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THE SIGNIFICANCE OF MINERALS FOR SOIL FERTILITY

N. I. GORBUNOV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Mineralogical analysis is used to solve the questions of soil genesis and agricultural chemistry in soil science. The immersion method is widely used both in the USSR and abroad. It is satisfactory for studying the coarse mineral fractions, which contain primary minerals. Every year, investigations are expanding on the use of X-ray, thermal, and electron microscopic methods. These methods are used effectively to study the most active soil fractions, in particular, clay and colloidal fractions. Of special consideration is the micromorphological method used to study intact thin sections of soil.

This article considers the importance and distribution of primary and secondary minerals in soils, the supply of nutrients, phosphate adsorption by minerals, and several other properties of fundamental importance for soil fertility. Mineral nutrients in soils may be combined before they are dissolved:

1. With primary minerals (feldspar, mica, pyroxene, amphibole, and others), i. e. enter into their crystal lattices.

2. With secondary minerals (clay and nonclay), whereupon the combination may take place in different ways: cations may enter into octahedra, compensate excess charge in the silica tetrahedra, and maintain residual valences on broken crystal surfaces (Fig. 1).

3. With surfaces, chiefly of secondary minerals but in part of primary minerals, as exchangeable ions.

4. In the non-exchangeable form. This form may have a different nature, but it is not necessary to outline the importance of ion adsorption through aging and crystallization of soil colloids.

5. In the form of insoluble and difficultly soluble salts, for example, basic iron, aluminum, calcium, and magnesium phosphates.

6. With organic matter, for example, humic acids, proteins, phytins, and others.

The solution of nutrients and their availability to plants depend on many factors, first of all, on microbiological processes occurring in soils and on properties of the plants themselves. Important roles are also played by the particle size and crystal structure of the minerals, their combinations with each other and with organic or mineral colloids, the aggregation, water, and air regimes of the soil, and the quantity and quality of humus. In addition, the availability of mineral nutrients is greatly influenced by physical chemical properties of the soil: exchange capacity, hygroscopicity, stickiness, hardness, swelling, cohesion, and others.

Primary minerals show a large effect on physical soil properties: water permeability, water-holding capacity, etc. It is known that feldspar, quartz, and mica are found primarily in the silt and larger fractions, and that their amounts determine the particle size classification of soils.

The elements combined with primary minerals are slightly available to plants, but gradually dissolve in the soil solution and then are taken up by plants. The primary minerals are not only a source of mineral nutrients, but also a source for the formation of secondary minerals: montmorillonite, kaolinite, halloysite, hydrous mica, goethite, gibbsite, sepiolite, palygorskite, chlorite, and others. In the primary and secondary minerals are found important nutrient elements: potassium, calcium, magnesium, iron, phosphorus, and microelements. Under certain conditions, the potassium of feldspars may be quite available to plants (3); that of mica is readily available (8a). The grinding of primary minerals is important for increasing the availability of mineral elements; the smaller the particle size, the more available are the mineral elements to plants.

The micas — muscovite, biotite, phlogopite

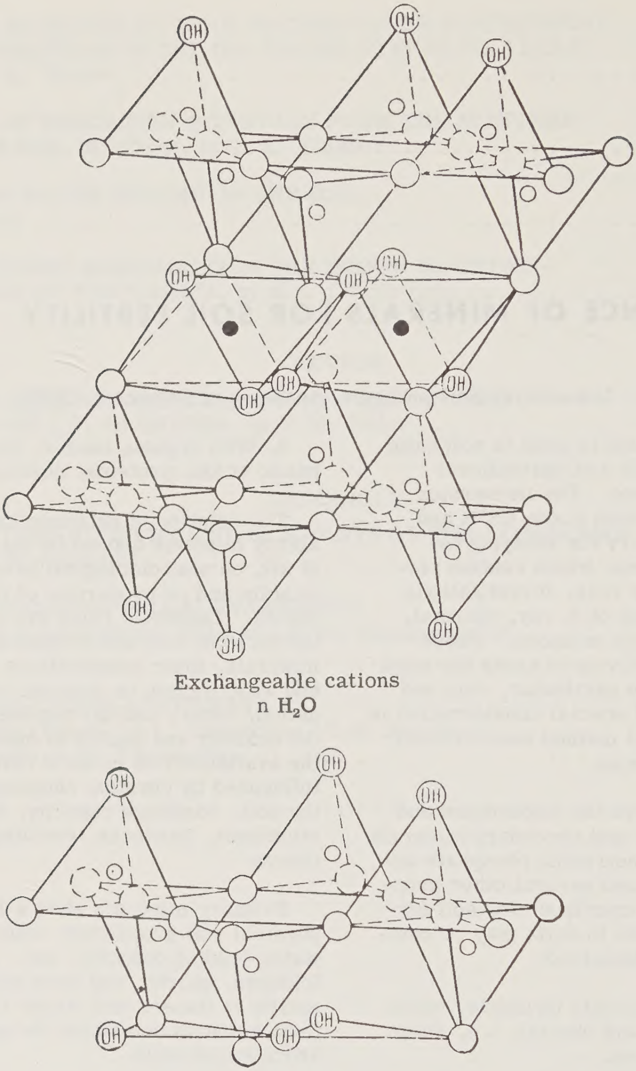

Fig. 1. - Schematic structure of montmorillonite and the position of exchangeable cations (according to Edelmann and Favejee).

— and hydrous micas — hydromuscovite (illite), hydrobiotite, and others — are important sources of potassium replenishing the soil solution. As a rule, soils rich in finely divided hydrous mica do not require potassium fertilizers, at least not in the first degree. Examples include some irrigated soils of Azerbaydzhan and the Central Asian republics, which are replenished upon irrigation with suspended material rich in hydrous mica. Hydrous mica is widely distributed in almost all soils except krasnozems and laterites. Because it is especially abundant in sierozems, the clay fraction of these soils contains much potassium. The potassium content of hydrous mica approaches 5%-6%, and of the <1 μ diameter soil particles, 1%-3%. Soils rich in kaolinite, halloysite, goethite, or gibbsite (e.g., krasnozems and laterites) contain very little potassium (Table 1). Of the minerals not containing potassium, quartz, opal, allophane, vermiculite, palygorskite, and others should be mentioned. An intermediate position is occupied by montmorillonitic minerals (montmorillonite, nontronite, beidellite). They usually contain potassium primarily in the exchangeable form.

We studied the mineralogical composition of krasnozems from southern USSR, China, and India, chernozems from Rostov, Kursk, and Voronezh Oblasts, sod-podzols and podzols

Table 1

Total chemical composition of $<1\ \mu$ diameter particles separated from minerals and soils, % of ignited sample

Minerals, soils, and location	Depth, cm	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	CaO	MgO	K_2O	Na_2O	$\frac{SiO_2}{R_2O_3}$	Exchange capacity, meq/100g of the fraction
Montmorillonite, Askana	—	65.0	21.9	4.0	26.9	0.26	5.82	0.24	0.09	4.5	109
Beidellite, Kiev Oblast'	—	56.1	27.8	12.4	40.2	2.1	1.49	0.6	0.07	2.6	60
Kaolinite, Glukhovtsy	—	54.3	43.0	1.3	44.3	0.24	0.13	0.02	0.01	2.1	20
Hydrous mica (illite)[a]	—	52.2	25.8	4.0	29.8	0.60	2.69	6.55	0.33	3.1	20—40
Hydrargillite (gibbsite)	—	—	100	—	—	—	—	—	—	—	None
Goethite	—	—	—	100	—	—	—	—	—	—	"
Well developed podzol, containing hydrous micas and montmorillonitic minerals	10—25	61.9	30.3	4.2	34.6	0.06	1.83	2.25	0.23	3.1	42
	74—85	58.4	23.3	15.0	38.4	1.44	2.90	2.57	0.16	3.0	36
	125—130	57.8	22.9	14.0	37.0	1.17	3.00	2.19	0.17	3.0	38
Ordinary chernozem, containing montmorillonitic minerals and hydrous micas	0—15	57.1	25.8	11.8	37.7	0.33	2.74	1.03	0.13	2.8	70
	70—80	56.8	27.0	10.4	37	0.34	2.72	1.58	0.11	2.8	63
	160—185	56.4	27.9	9.1	37	0.39	2.26	2.35	0.23	2.8	62
Sierozem with hydrous micas predominating	0—4	56.4	20.9	10.8	31.7	0.58	4.10	3.80	0.2	3.5	45
	18—33	58.5	21.6	9.6	31.3	0.57	4.17	3.10	0.25	3.6	47
	116—125	58.0	21.7	8.7	30.4	0.18	4.57	3.10	0.30	3.6	50
Krasnozem, containing kaolinitic minerals, goethite, and gibbsite	0—20	42.1	38.1	16.7	54.8	Trace	1.23	0.26	0.1	1.4	33
	35—40	40.7	39.6	15.8	55.4	"	0.64	0.14	0.1	1.3	29
	150—200	40.8	39.1	18.8	57.9	"	1.00	0.22	0.1	1.3	31

---

[a] On oven-dry weight.

from Karelian ASSR, Smolensk, and Moscow Oblasts. Only part of the experimental material is presented here. Our investigations showed that podzols and chernozems formed on morainic clays contain similar associations of finely divided minerals, although there were differences between them. In the <1 μ diameter fraction of these soils, montmorillonitic minerals (beidellite)[1] and hydrous micas predominate, but also small amounts of quartz and rarely kaolinite and sesquioxide minerals are found. The latter are more abundant in podzols, especially in the illuvial horizon, and are found in a poorly crystallized form, as indicated by diffused lines and dark backgrounds on X-ray diffraction patterns.

Some data indicating similar associations of finely divided minerals in podzols and chernozems are: 1) thermal analyses of the <1 μ diameter particles separated from these soils show similar temperature effects (Figure 2); 2) X-ray diffraction patterns, including those from oriented aggregates after saturation with ethylene glycol, show similarities; 3) the $SiO_2:R_2O_3$ ratios in the clay fractions of both soil groups are similar; 4) the exchange capacities of the clay fractions are similar; 5) the potassium content of the <1 μ diameter particles of podzols and chernozems is considerable-sometimes greater in podzols than in chernozems (Table 1); 6) kaolinite crystals are seldom seen on electron micrographs of podzols. The low cation exchange capacity of podzols, especially in the eluvial horizon, seems to indicate the prevalence of kaolinite. But here we forget that exchange capacity depends not on the whole soil, but on its finely divided portion. This was shown by K. K. Gedroyts and other investigators. We point out the article of Chernov (10) as recent work on this question. To demonstrate the high cation exchange capacity in the clay fraction of podzols, we calculated it on the basis of Chernov's data on the exchange capacity of the whole soil and its content of <1 μ diameter particles (Table 2). The results show that the capacity of this fraction is two to four times greater than that of kaolinite. Similar results were obtained by recalculating the data of other authors (7), and also by direct determination of the cation exchange capacity of clay fractions (Table 3). They are similar in podzols and chernozems, and vary from 36-56 meq/100g of <1 μ diameter particles. Kaolinite does not have such a high cation exchange capacity. The fact that the exchange capacity of the <1 μ

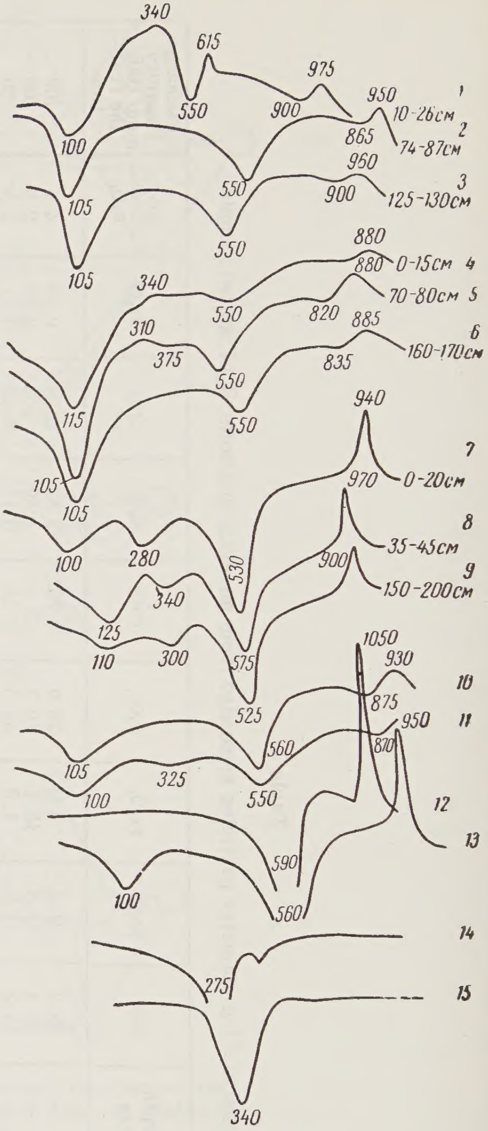

Fig. 2. - Thermal analysis patterns of the <1 μ diameter particles separated from soils and minerals.

1,2,3 - strongly podzolized, Yartsevo, Smolensk Oblast'; 4,5,6 - chernozem, Kursk National Forest; 7,8,9 - krasnozem, Chakva, Georgian SSR; 10 - beidellite from soil; 11 - hydrous mica; 12 - kaoline; 13 - halloysite; 14 - gibbsite; 15 - goethite.

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[1] Since the term "beidellite" has recently been under dispute, some explanation is required. Some investigators (Grim and others) consider it expedient to exclude this term from use. Others (Brown, Marshall, and others) consider beidellite to be a mineral of the montmorillonite group, distinguished from montmorillonite by the presence of aluminum in the tetrahedra. A third group considers beidellite to be an interlayer mineral composed of montmorillonite and kaolinite (Vikulova). Pending a decision from the commission on nomenclature, we will understand that beidellite is a mineral with properties intermediate between those of montmorillonite and hydrous mica: $SiO_2:R_2O_3$ ratio near 3, cation exchange capacity equal to 55-60 meq/100g and strong swelling.

Table 2

Cation exchange capacities of sod-podzols and their <1μ diameter particles, meq/100g

Soil	Depth, cm	Content of <1 μ diam. particles, %	Exchange capacity of the soil	Exchange capacity of the <1 μ diameter particles
Sod-podzol	0—5	22.5	14.5	64.4
	10—15	24.2	14.5	60.0
	15—20	25.0	14.8	51.0
	20—25	16.6	12.6	75.9
	40—45	18.5	12.7	68.6
	70—75	15.2	9.6	63.1
	100—105	14.0	9.9	70.7
Sod-podzol	0—10	14.1	8.3	58.8
	15—20	14.4	8.6	59.7
	25—30	14.3	7.2	50.8
	50—55	21.3	11.0	51.6
	105—110	19.0	11.6	61.0

Table 3

Cation exchange capacity and potassium content of the <1 μ diameter particles of soils

Soil and location	Depth, cm	Fraction <1 μdiameter particles, %	Cation exchange capacity, meq/100 g of fraction <1 μ diameter	Potassium content, %
Sod-podzol on glacial till, Moscow Oblast'	0—10	12.4	not det'd.	2.70
	29—37	13.4		2.44
	39—47	19.8	46.2	2.04
	48—56	22.2	not det'd.	2.05
	100—110	33.9		1.85
	230—270	18.6	48.9	1.77
Well developed podzol, Yartsevo, Smolensk Oblast'	10—25	5.1	42.2	2.25
	74—85	14.7	36.5	2.57
	125—130	16.6	37.9	2.19
Podzol on moraine, Zaonezh'ye, Karelian SSR	8—11	48.0	55.7	
	23—34	36.6	41.7	2.28
	70—75	28.5	44.7	2.64
Ordinary chernozem, Kursk	0—15	24.1	81.0	1.03
	70—80	29.9	72.4	1.58
	160—185	32.9	57.0	2.35
Gray-brown soil on granite residuum, Kazakhstan	0—5	13.7	29.3	2.2
	16—24	16.2	29.0	2.2
	50—60	22.6	not det'd.	2.28
Krasnozem, Chakva, Georgian SSR	0—20	38.0	33.2	0.26
	35—40	47.0	29.4	0.14
	150—200	30.6	31.0	0.22
Laterite, Africa	20—36	32.3	10.0	0.05

diameter particles of podzols is somewhat less than that of chernozems is explained by the relatively greater quantity of quartz and amorphous material (SiO_2, R_2O_3), which have no cation exchange properties in podzols. Together with the similarities in finely divided minerals in chernozems and podzols, there are great differences between them, consisting chiefly in the distribution of these minerals through the profile. In chernozems they are distributed rather uniformly, while in podzols they are leached from the podzolized horizon and accumulate in the illuvial horizon. Sesquioxides sometimes accumulate in this horizon of podzols in significant quantities, and from concretions and ortstein, but not in chernozems. The podzolized horizon is low in fertility as a result of leaching colloidal and clay particles from it.

It should be emphasized that the foregoing considerations apply to soils formed on Quaternary materials, which are very widely distributed in European USSR. Entirely different mineral associations are observed in soils formed on older materials, for example on granitic residuum. Podzols on this material are found in the Urals, Yakut, and Karelia, and chernozems in Zaporozh'ye and other Ukrainian districts. In such podzols and chernozems the predominating mineral is kaolinite, accompanied by hydrous mica, mica, quartz, and montmorillonitic minerals. The prevalence of kaolinite lowers the fertility of these soils.

Generally there is more magnesium than calcium in the clay fraction (Table 1), but there is more calcium than magnesium in the whole soil (6a). Thus, magnesium is combined primarily with secondary minerals. This element enters into crystal lattices if their octahedral layers consist of brucite, or it may be found in the exchangeable form. Minerals of the sepiolite-palygorskite group, some micas and hydrous micas, and several montmorillonitic minerals are the richest in magnesium. Calcium is usually found in the exchangeable form in secondary minerals and organic matter, or combined with primary minerals. There is usually little calcium in the crystal lattice of secondary minerals. The mineral salts found in soils (carbonates, gypsum, and others) are not considered in this article. Phosphorus enters into primary minerals (e. g. apatite), and upon weathering it precipitates in the form of slightly soluble salts or is adsorbed by secondary clay and other minerals: goethite, gibbsite, amorphous sesquioxides, montmorillonite, and others.

Table 4

Microelement contents in Quaternary deposits from northern Kazakhstan and their $<1\ \mu$ diameter particles[a]

Element	In deposits, % x 10^3	In the $<1\ \mu$ diameter particles x 10^3,%	Element	In deposits, % x 10^3	In the $<1\ \mu$ diameter particles x 10^3,%
Ti	405	30	Zn	8.4	15
Mn	112	77	Cu	6.8	10.7
V	12	11.3	Ni	2.1	2.5
Zr	6.8	7.2	Co	1.2	0.9
Ga	4.3	6.3	Y	5.0	5.0
Sc	5.2	9.5			

---

[a] Results of 200 spectrographic analyses, data of V. V. Dobrovol'skiy (7).

There is very little data on the distribution of microelements in clay and coarser fractions of soils, and their forms of combination with minerals have not been studied. From Table 4 it follows that certain microelements (copper, zinc) remain combined with the clay fraction after weathering of primary minerals, and as a result of their small particle size are more available to plants. Not only the total content of mineral elements, but also their adsorption on finely divided particles of the soil, are important for soil fertility. In this connection we may refer to experiments of Soviet (1, 2, 8, 9) and foreign authors (12-27) on phosphate adsorption by minerals and soils. In these investigations, the role of sesquioxides, soil colloids as a whole, and clay minerals in phosphate adsorption was shown.

Especially broad investigations were carried out by Askinazi and Ginzburg (2). These authors presented data on phosphate adsorption by various minerals as affected by grinding, time of reaction, pH, heating, and other conditions. They also presented a critical literature survey.

We will consider the results of our experiments on phosphorus adsorption by clay minerals, soils, and sesquioxides with varying degrees of crystallinity (Table 5). Hydrous iron and aluminum oxides may occur in soils in amorphous form, in crystalline form (goethite, gibbsite), and in transition states between amorphous and crystalline. At present there are no exact quantitative methods for determining amorphous and crystalline sesquioxides, but thermal analysis may suggest the presence of these forms and their approximate amounts. It is known that upon heating, goethite (Fe_2O_3 x H_2O) gives an endothermic reaction at 340°C, and gibbsite (Al_2O_3 x $3H_2O$) at 275°C. From the magnitude of these effects the approximate quantities of crystalline sesquioxides may be determined. In the amorphous state these materials give a thermal reaction at approximately

Table 5

Adsorption of P_2O_5 by minerals, soils, and amorphous materials (data of G. S. Dzyadevich)

Substance	Time of reaction, days	Crystallinity of substance. Minerals	P_2O_5 adsorbed, mg/100 g	Equilibrium pH of solution
Ferric hydroxide, 10 days after preparation	1	Amorphous	9500	5.5
Aluminum hydroxide, 10 days after preparation	"	Amorphous	15680	5.5
Ferric hydroxide, dried at 105°C	"	Partially crystallized	4030	5.6
Aluminum hydroxide, dried at 105°C	"	Partially crystallized	6620	5.6
Ferric hydroxide, dried at 340°C	"	Crystallized (goethite)	88	4.7
Aluminum hydroxide, dried at 300°C	"	Crystallized (gibbsite)	114	4.7
Kaolinitic clay, Pologi, Ukraine SSR	"	Criptalline kaolinite	50	4.9
The same kaolinitic clay, ground in the dry state	"	X-ray amorphous kaolinite	8000	5.9
Montmorillonite clay (askanite)	"	Crystalline montmorillonite	450	4.9
The same montmorillonitic clay, ground in the dry state	"	X-ray amorphous montmorillonite	4200	5.9
Halloysitic clay	"	Crystalline halloysite	1200	4.9
The same halloysitic clay, ground in the dry state	"	X-ray amorphous halloysite	8000	5.8
The same halloysitic clay, puddled in water	4	Dispersed halloysite	2650	5.0
Halloysitic clay plus 5% humic acid, puddled in water	"	Halloysite, partially covered with humic acid	1700	4.9
Aged ferric hydroxide	"	Partially crystallized	1660	4.8
Aged ferric hydroxide plus 5% humic acid	"	Partially crystallized and covered with humic acid	1500	4.8
Krasnozem, 0—20 cm, Chakva	1	Kaolinite, gibbsite, goethite, amorphous material	775	4.7
Chernozem, 0—15 cm, Kursk	"	Montmorillonitic minerals, hydrous micas, organic matter	50—90	4.7

100°C. The lines of an X-ray pattern also indicate the degree of crystallinity. We have examined this question in detail (4, 5, 6). The adsorptive power for phosphates depends on the indicated composition in various ways. The character of sesquioxides in soils (nodules, concretions, coatings, ortstein, filaments, etc.) has great importance for the binding of phosphorus. For example, amorphous coatings of sesquioxides may adsorb more phosphate than crystalline concretions, although the total content of iron (and aluminum) in the former may be much less than in the latter.

In order to study phosphate adsorption as affected by degree of crystallinity, the following experiments were set up. Aluminum and iron hydroxides were prepared by reacting their sulfates with ammonia and washing out the electrolyte. Then one portion of the hydroxides was dried at room temperature, another at 105°C and a third at 300 or 340°C. These drying temperatures were chosen on the basis of earlier experiments on crystallization (4,5). In particular, temperatures of 300 or 340°C correspond to the evolution of water from gibbsite or goethite (Fig. 2). Clay minerals were made amorphous by grinding in the dry state. The degree of fineness was controlled by the disappearance of the diffraction lines on X-ray patterns and the endothermic reaction at 550-600°C, as described in a special article (6).

The preparations were treated with monocalcium phosphate, 9 g/l, at a 1:10 soil-solution ratio. The pH of the initial solution was 4.7. The data in Table 5 show that amorphous sesquioxides adsorb ten times more phosphorus than crystallized ones, i. e. than goethite and gibbsite. If phosphate ions were adsorbed on amorphous hydroxides, which later crystallized upon drying, then the phosphate would not be expected to be available to plants.

The data on phosphorus adsorption by different clay minerals and soils deserve special attention. In the literature there are indications that kaolinite sometimes adsorbs more P_2O_5 than montmorillonite. From the chemical composition of kaolinite and montmorillonite, the former would be expected to adsorb more phosphorus than the latter. In kaolinite the SiO_2:R_2O_3 ratio is two, but in montmorillonite, four. Thus, the relative content of aluminum, with which phosphorus probably combines, is greater in kaolinite than in montmorillonite. However, it was found that the active aluminum (that located on crystal surfaces) was lower in kaolinite, since it had large crystals, and the aluminum inside the octahedra was only partially able to react with phosphorus. On the other hand, the total aluminum content is less in montmorillonite, but the active content is greater because of the small particle size of this mineral. As a result, kaolinite adsorbed less P_2O_5 than montmorillonite and soils in our experiment. This conclusion agrees with that of Askinazi and Ginzburg (2). The data on phosphorus adsorption by kaolinite and halloysite also indicates the importance of particle size. These minerals have the same chemical composition and similar structures, but halloysite is distinguished by smaller particle size and greater hygroscopicity. This difference is well illustrated by thermal analysis and electron microscopy (Fig. 3). Thermal analysis of halloysite shows a large endothermic reaction at 100°C, but not with kaolinite. The electron micrographs show that kaolinite crystals are larger than halloysite crystals. As a result of the small particle size of halloysite, it adsorbs more phosphorus than kaolinite and montmorillonite, and even more than krasnozem. Even though there is much sesquioxide in krasnozem, the thermal reaction at about 300°C shows that it occurs in crystalline form (goethite and gibbsite), and thus has little surface.

Experiments on phosphate ion adsorption by X-ray amorphous minerals were established for the purpose of explaining its mechanism. Several authors have assumed that phosphate ions exchange for the OH ions of clay minerals. This supposition is supported by the alkalinity of solutions as a result of displacement of OH ions from the adsorbent. However, Askinazi's experiments showed that the alkalinity was low in comparison with phosphate adsorption. The supposition is also negated by the results of experiments with clay minerals, in which the crystal lattice has been destroyed by vigorous grinding. It is known that OH ions are part of the structure of octahedra. Since diffraction lines are not observed on X-ray patterns after grinding clay minerals, one may assume that the octahedral layer is destroyed. Also, thermal analysis after grinding does not show the effect usually observed. Thermal analysis curves for kaolinite and halloysite after grinding are similar to those for allophane (6). After the destruction of octahedra, there is no basis for discussing the exchange of their OH ions for phosphate ions. Since phosphate adsorption greatly increases after grinding, it must be assumed that these ions are combined with aluminum.

The results of experiments on phosphate adsorption by minerals with destroyed lattices explained the relationship observed by several authors between the silica-sesquioxide ratio in minerals and their phosphate adsorption. In crystalline clay minerals there is no such relationship, since adsorption concerns only the aluminum (and iron) on their surfaces. After destruction of the crystal lattice, the relationship becomes very clear. For example, in kaolinite the ratio of aluminum oxide and silica is twice that in montmorillonite, and after grinding, kaolinite adsorbs twice as much P_2O_5 as montmorillonite.

In order to decrease phosphate adsorption, part of the sorbents were treated with humic acid; the mixture was ground while moist, then dried and treated with a solution of monocalcium phosphate. It is known that humic acids do not adsorb phosphate ions, so we excepted that covering the minerals with them would reduce the mineral's capacity to adsorb P_2O_5. To test this, an experiment was set up on the adsorption of phosphate from a solution of monocalcium phosphate by samples of halloysite, which had been ground in water with and without additions of humic acid (5%). The humic acid was separated from a Kammennaya steppe chernozem by Tyurin's method. The sample without humic acid adsorbed 2650 mg, and that with humic acid only 1700 mg P_2O_5/100 g. Thus a layer of humic acid partially covered the halloysite and active aluminum surface. Similar results were obtained upon adding organic matter to iron hydroxide

Clay and other minerals have great significance for physical soil properties. It is known that soil swelling, stickiness, permeability, hygroscopicity, and the related available moisture for plants depend in some degree or other on the mineral composition of soils. As an example, data on swelling obtained with the method and apparatus of A. M. Vasil'yev (6a) are presented in Table 6. The degree of swelling influences the formation of crevices and crusts in soils, which in turn influence yields.

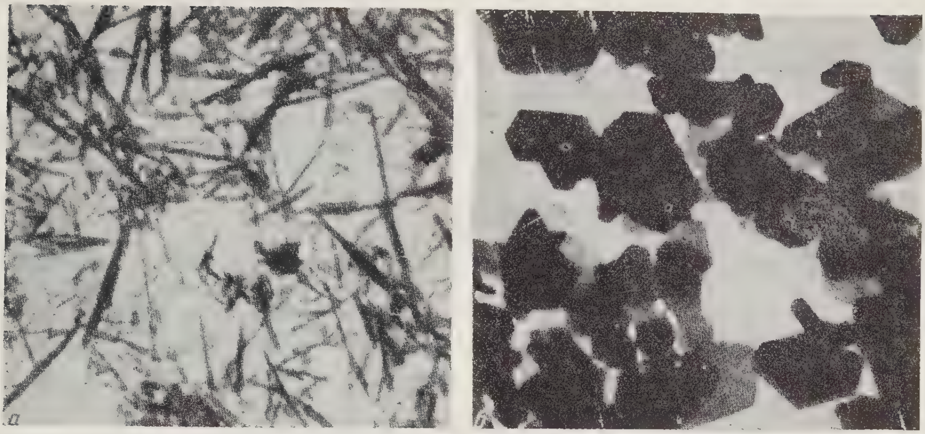

Fig. 3. - Electron microscope photographs, x 12,500.
a - halloysite; b - kaolinite.

Table 6

Swelling of minerals in percent of the initial volume

Mineral	Swelling
Montmorillonite (askan gel)	96
Monothermite	17
Hydrous mica	12
Kaolinite	4.5
Quartz	0

Finally, we mention the importance of inely divided minerals for structure formaion. Water stability of aggregates depends ot only on the quantity and quality of humus, ut also on the composition of the minerals hich interact with the humus. This question as considered in detail in Khan's article (11), so we merely refer to the fact that structure is ost water stable when humus interacts with ontmorillonitic minerals and hydrous mica, nd least water stable when it interacts with uartz, amorphous silica, and kaolinite. Sesuioxides are especially important for strucure formation. When they occur in the amorhous state, they react with organic acids, orming stable organic-material complexes. hese complexes may move in the soil profile nd deposit as ortstein, smears, and occluions. If the sesquioxides crystallize, they orm water stable aggregates. Such a phenmenon is observed in krasnozems (4). It ppears that these principles explain the poor ggregation in sod-podzols and the good aggreation in krasnozems.

Conclusions

1. The primary minerals (feldspars, micas, pyroxenes, amphiboles, etc.) found in soils are sources replenishing the nutrient elements in solution: potassium, calcium, magnesium, (probably microelements), etc. Also, clay and non-clay minerals, which are a very important part of the soil adsorption complex, are formed from primary minerals during weathering and soil formation. The primary and secondary minerals explain a number of soil properties: cation exchange capacity, swelling, P_2O_5 adsorption, etc.

2. Of the secondary minerals in soils, hydrous mica is most widely distributed and is a source of potassium for plants. In the fraction of <1 μ diameter particles of sod-podzols and chernozems formed on Quaternary materials, montmorillonitic minerals and hydrous mica predominate, with mixtures of sesquioxide minerals and rarely, kaolinite. The amounts and distribution of these minerals in the profile are different in chernozems and podzols. Also, there is usually more amorphous material in podzols. Chernozems and podzols formed on older materials contain significant quantities of kaolinitic minerals in the <1 μ diameter fraction. Krasnozems contain mainly kaolinitic minerals, goethite, and gibbsite. Hydrous mica predominates in the <1 μ diameter fraction of sierozems. Since minerals differ in chemical composition and physical chemical properties, their significance for soil fertility varies.

3. Data are presented on P_2O_5 adsorption by amorphous and crystalline minerals — clays (kaolinite, halloysite, montmorillonite) and nonclays (goethite, gibbsite). The role of humic acids, which interact with minerals to reduce

phosphorus adsorption, is shown.

4. Phosphorus adsorption by montmorillonite, halloysite, and kaolinite, after grinding to an X-ray amorphous condition, is nearly proportional to the $SiO_2:R_2O_3$ ratios in the minerals. For example, halloysite and kaolinite have equal $SiO_2:R_2P_3$ ratios, and they adsorb equal amounts of phosphorus after grinding to destroy the crystal structure. In montmorillonite, this ratio is only half as great as in kaolinite, and correspondingly it adsorbs about half as much phosphorus.

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RESULTS OF STATIC INVESTIGATIONS ON THE WATER REGIME OF SANDS AND SAND-COVERED CLAYS UNDER FOREST NEAR EBERSWALD[1]

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The Institute for Forest Soils and Habitation of the Forestry Faculty, Humboldt University, has carried out static investigations of the water regime of forest soils since 1954. In addition, the distribution of roots in soils was studied. In 1957, investigations were started on nutrient element cycles and movement in soils. Meteorological observations were also made on some areas by collaborators from the Institute for Forest Meteorology.

The soils under investigation were formed on Vyurmskiye glacial deposits, consisting partly of sands of the Eberswald wooded glacial outwash, and partly of morainic clay loams under sandy deposits.

The particle size analysis of the sandy soils was as follows: particle diameters of 0.2-0.1 mm (fine sand), 55%-75%; 0.1-0.05 mm (very fine sand), 15%-20%; 0.5-0.2 mm (medium sand), 10%; silt and clay, <5%.

The two-layered soils consisted of: 1) medium sands 1 m thick over sandy to sandy loam glacial till, or over clay bands consisting of alternate layers of silt and clay (quadrat 87), or 2) fine sands 60 cm thick of the following composition: 0.5-0.2 mm, 20%-30%; 0.2-0.1 mm, 35%-55%; 0.1-0.05 mm, 15%-25%; <0.05 mm, 5%-8%; over sandy loam (70%-75% sand, 15% silt, 10% clay) grading into a highly calcareous moraine at a depth of 150 cm (quadrat 34).

The sandy weakly or medium podzolized brown forest soils are formed on two-layered deposits. It is not yet known whether the lower part of the sandy soil over glacial till arose by movement of fine particles into the till or whether it was deposited on this till. In the C horizon of some soils a brown layer is found containing iron hydroxides which affect the water regime.

Fine sandy soils were studied on the following three experimental areas:

1. Pine Forest 75 Years Old (quadrat 123) site quality index IV with a ground cover of bilberry and heather (it will be referred to as pine-bilberry, but does not correspond to this term as used by Sukachev). The coarse humus forest litter is up to 5 cm thick. The soil is weakly or moderately podzolized.

Pine root distribution was studied by H. D. Hausdörfer in this soil as well as in the other investigated soils, using the following method. Roots were exposed in cut-sections (mostly 3-4 m long and 2-3 m deep), and their positions and numbers were plotted graphically. The fine roots (<1 or 2 mm in diameter) were counted in 10 by 10 cm quadrats on the sections. Fine root distribution was plotted on charts, on which each quadrat was represented by different cross-hatching according to the number of fine roots present. The quadrats with the most and thickest cross-hatches contained the most roots. In the upper 50 cm layer, the amount of fine roots was determined by weighing.

The pine-bilberry root distribution was superficial. Almost 80% of the fine roots were located in the upper 40 cm, and about 95% in the upper 60 cm. There were an average of 8-9 roots <1 mm in diameter/100 cm^2 in the upper 40 cm. In the deeper layers of soil, fine roots were found only in certain layers, several mm thick and rich in heavy minerals.

2. Pine Plantation 55 Years Old (quadrat 121), site quality index II, with a ground cover of green moss and sparse grass (pine-green moss). The litter is of the mor type, and about 5 cm thick. The soil is a podzolized brown forest soil with numerous brown bands in the BC horizon. Roots are more abundant and

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[1] Presented at the First Delegates' Congress of Soil Scientists, May, 1958.

penetrate deeper into this soil than into that under pine-bilberry. About 55%-60% of the fine roots are located in the upper 50 cm layer, and 20% in the next 50 cm layer. About 20% of the roots were also found in the second meter. They were more frequently found in sandy loam bands or those rich in iron. There were 8-9 fine roots per 100 cm² in the upper 50 cm layer.

3. Mature Beech Woods Over 100 Years Old (quadrat 122), site quality index III/IV, with poorly developed grass ground cover. The mor type litter was more decomposed than under pine-green moss, and 2-3 cm thick.

On the average, there were 19-26 fine roots per 100 cm² in the upper 50 cm layer, i. e. two or three times as many as under pine plantations. Of the total amount of fine roots, 80% was in this layer. At depths of 1-1.2 m and about 2.5 m, numerous fine roots were found in strongly developed bands rich in iron.

The soils on two-layered deposits were investigated under mixed pine and beech plantings, in which the pine was over 100 years old and the beech 50-60 years old. Grass ground cover was poorly developed, and barberry predominated. The humus was mull-type mor, i. e. more favorable than under pure beech plantations on sand.

The roots under beech clumps were distributed in two clearly boundary layers, one in the upper 50 cm of sand, the other in the clay.

In the medium sand, 1 m thick, laying over clay loam (quadrat 87), only 27%-28% of the fine roots were contained in the upper 50 cm (Fig. 1). The next 50 cm of sand contained almost no roots. Beginning at a depth of about 1 m is the clay loam, containing almost 70% of the fine roots. At a depth of 2-2.5 m there are as many fine roots as in the upper 50 cm of sand (27.5%). On the average, there were 13-24 fine roots per 100 cm² in the upper 40 cm, and 13-20 fine roots per 100 cm² in the clay loam at a depth of 2-2.5 m.

In the slightly clay fine sand 60 cm thick over clay loam (quadrat 34), more than 50% of the fine beech roots were in the upper 50 cm. Under this is a thin zone over clay loam with fewer roots. The clay loam is uniformly penetrated with roots (about 40% of the fine roots) down to the transition to calcareous moraine (at about 1.5 m depth). On the average, there were 8-9 fine roots per 100 cm² in the upper 50 cm, and 3-4 fine roots per 100 cm² in the clay loam at a depth of 1-1.5 m.

On the average, there were fewer roots under the mixed plantations than under pure beech clumps (5-6 fine beech roots and 0-1 fine pine roots per 100 cm²). Fine pine roots were confined mostly to the sandy layer (83% of them were found in the upper 50 cm of sand, and only 5% in the upper 50 cm of clay loam). On the other hand, 27% of the fine beech roots were found in the upper 50 cm of clayloam. Although only 45% of the forest stand was occupied by beech, 92% of the fine roots (<1 mm in diameter) consisted of beech.

Studies of the soil moisture were measured by electrical conductivity and weekly soil sampling. The determinations were made to a depth of 3-4 m. Electrical conductivities, as well as soil sampling, were measured in triplicate, but beginning in 1957, with 10 replicates in the surface layer and 5 replicates below 40 cm.

In the first years, electrical conductivity was measured in the soil by placing carbon rod electrodes horizontally equidistant from each other. Later they were replaced by stainless steel electrodes. At the same time, resistance thermometers were installed for measuring soil temperature. The electrodes were wired to a Weston apparatus, supplied with alternating current (1 kilocycle). The source of current was a motorcycle battery. The direct current was converted mechanically to alternating current. The accuracy of the readings was about 0.5%-1.0%.

A graphical conversion of conductivity readings to water content was made. The logarithms of all conductivity readings for one year were plotted against the moisture contents determined in the soil samples during the same time. In this way a dense distribution of points was obtained, through which a straight line was drawn. This straight line gave the volume percent soil moisture corresponding to the electrical conductivity readings.

The scatter of points from the straight line was sometimes considerable. Even so the correlation coefficient (even with triplicate measurements) averaged 0.7. This scatter was partially due to local variations in moisture, and probably partially to variations in electrolyte content. Variations in contact between the electrodes and the soil play no role in sandy soils. Moisture values calculated from electrical conductivity measurements fully correspond to the average yearly value, but in individual cases they may deviate somewhat from the actual soil moisture value. Comparisons between moisture determinations by the electrical conductivity and weight methods show clearly that curves obtained by the first method are not only correct, but, because of the numerous observations, characterize soil moisture more fully. For example, they allow one to observe the penetration of rains into soils and drying of soil at different depths. The question of absolute moisture values in individual cases is not yet resolved. The average values of triplicates deviate from those of three simultaneous moisture determinations by weight by not more

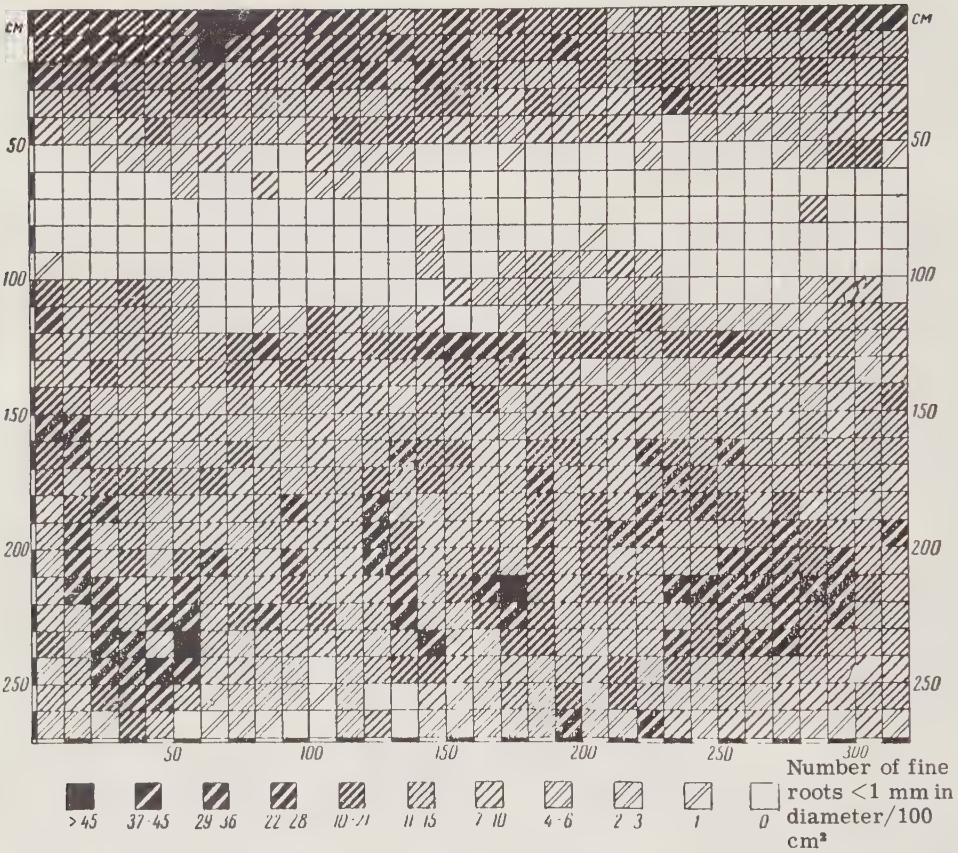

Fig. 1. - Number of fine roots (<1 mm diameter) per 100 cm^2 in the soil on two-layered deposits under beech, Khorin, quadrate 87.

than 1.5 volume percent in 68% of the cases, and by not more than 2.8% in 95% of the cases. Thus, differences between moisture determinations by the electrical conductivity and weight methods, in the vast majority of cases, are within the limits of error of moisture determinations by the weight method.

The moisture studies were supplemented by bulk density determinations, and also by moisture retention determinations at different moisture tensions. These measurements were always carried out on samples with undisturbed structure. At moisture suctions <1 atm, Sekera's apparatus (2) was used, and at moisture suctions of 3-15 atm, the pressure membrane apparatus of Richards (1) was used. Such measurements were used to construct chrono-isopleths of moisture suction as well as moisture content.

We now consider the results of these measurements for the previously mentioned locations. The moisture in the upper meter layer of the three fine sandy soils studied in the summer of 1955 is presented in Figure 2. The measurements were carried out in triplicate.

The spring of 1955 was dry. In May only 23 mm of rain fell, i. e. half the normal amount. At the beginning of June, the precipitation was considerably greater, and in the remainder of June and in July, it was normal. August was too dry, but at the end of the month an amount of precipitation unusual for this area fell. From the middle of September to the middle of October, almost precipitation was recorded.

Soil drying during the dry spring was greatest under pine-bilberry and relatively less under beech. Summer rains penetrated into the soil more and deeper under pine-green moss and beech (with mor type humus) than under pine-bilberry, where most of the summer precipitation could not penetrate significantly through the coarse humus litter.

The sandy soils under beech plantations were wettest in the spring, but in the fall they showed more drying than the others. This is probably brought about by more intensive root development. In pine-bilberry, because of the surface

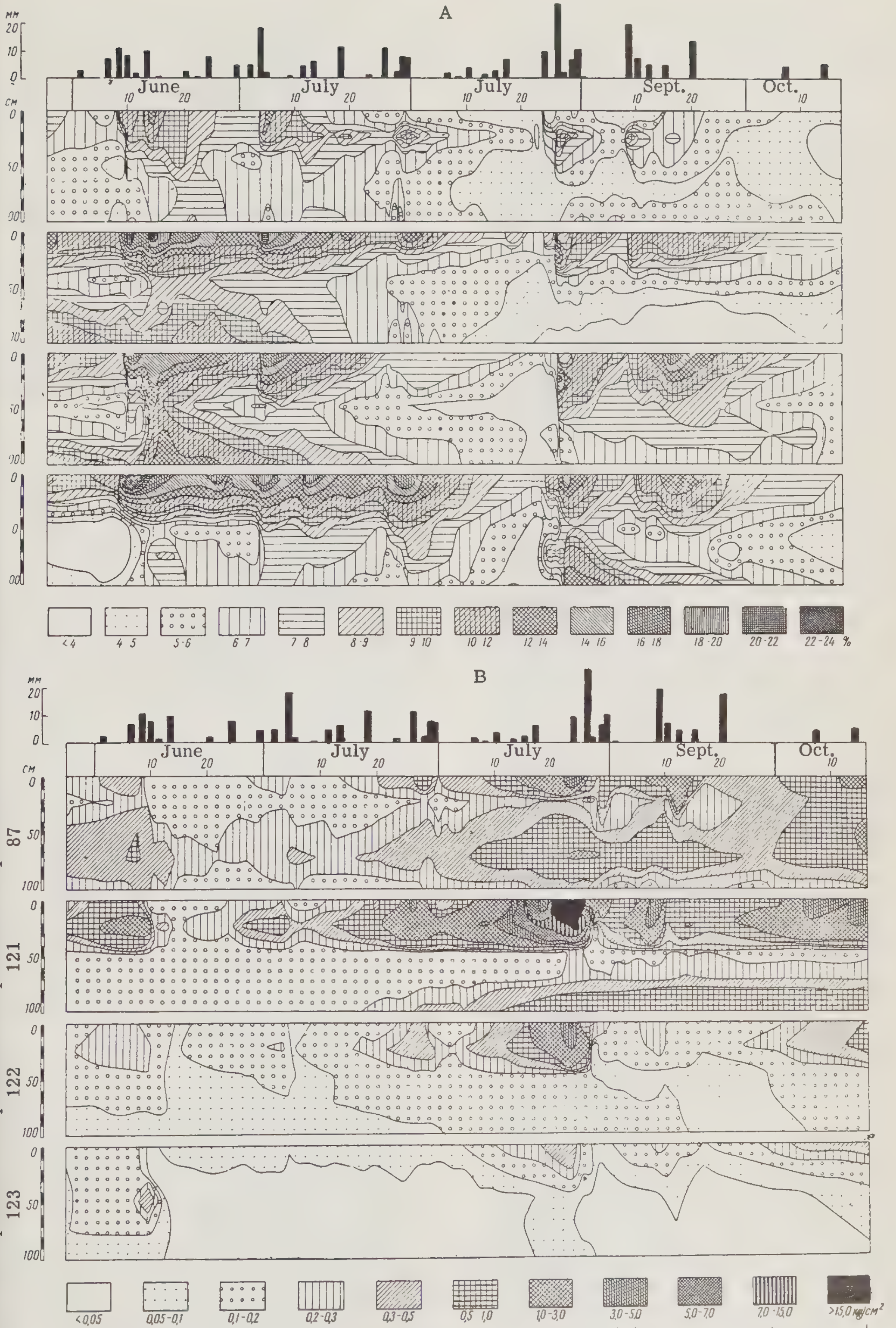

Fig. 2. - Chrono-isopleths of soil moisture from electrical conductivity measurements on sandy soils (quadrats 121, 122, 123) and in the sandy soil 100 cm thick over morainic clay loam (quadrat 87). A - Volume percent of soil moisture; B - Moisture suction (kg/cm²)

distribution of the pine and bilberry roots and also the more infrequent soil wetting, drying increased from the surface downward. The least soil drying was observed under pine-green moss.

The moisture status in the meter thick sand over glacial clay loams under pine-beech stand (quadrat 87) in the summer of 1957 differed from that of the fine sands in the following way. During the dry spring, the drying was greater than in the fine sands. But, because of the well decomposed litter (mull-type mor) and somewhat coarser sand, the summer rains penetrated more and deeper into the soil than under beech on fine sand. The especially heavy rains at the end of August caused water to stand over the glacial clay loam. In spite of the fact that the lower part of the sandy soil contained almost no roots, drying increased with proximity to the surface. Apparently, the sand lost part of its water to the clay loam, which was heavily penetrated with roots.

Chrono-isopleths of soil moisture suction supplemented those of moisture content, especially from the plant physiological standpoint. Thus, the surface 20-30 cm of soil under beech dried out most in the late summer and fall. Late in the summer, the wilting percentage was even exceeded (15 atm). During the last half of the summer, the subsoil showed values of 0.5-1.0 atm. Such values were not found in the subsoil under pine-green moss or mixed pine and beech plantations. Under pine-bilberry, the soil moisture suction reached 0.3-0.5 atm at a depth of 75 cm even in early summer, and 0.5-1.0 atm in late summer and early fall. Thus, soil under pine-bilberry contained the same amount of available moisture as the soil under beech (excluding the uppermost soil layer in the fall).

A further example is given by the moisture determinations in 1957. These were carried out with 10 replications in the upper 40 cm, and 5 replications below 40 cm on the two-layered soil (60 cm of sandy loam to fine sand over glacial clay loam) under mixed pine and beech plantations (quadrat 34, Fig. 3). In 1957, the first quarter of the year was normal in precipitation, and the second (April through June) was extremely dry. Much rain fell in July, August and September were moist, October and November were relatively dry.

The following soil moisture characteristics were observed. In the summer, the sandy layer dried out most strongly below 25 cm from the surface. The upper 25 cm was frequently and intensely wetted by summer rains. In addition, this layer held more moisture because of a higher humus content in the uppermost layer. Roots dried out the lower part of the sandy layer, and part of the water was absorbed from the sand by the glacial clay loam, which was thickly penetrated with roots. Standing water over the clay loam was not noticed in the summer. About July 1, the soil was quite uniformly moist (18-19 volume percent), after which it gradually dried out to about 15%-16%. Slow moisture accumulation in the clay loam did not begin until January 1958 and included only about 0.5 m of the clay loam layer by the middle of February.

In evaluating these quantities, we must consider that the moisture holding capacity of the clay loam layer is twice that of the sand (20%-25% compared to 10%-15%), and that the upper layer of sand, because of its higher humus content, has a much higher moisture holding capacity (15%-20%) than the lower layer. The moisture holding capacity of this clay sand is much greater than that of the fine sand investigated in 1955. This explains why the summer rains penetrated deeper in 1955.

The chrono-isopleths of moisture suction also showed that the sands lying over clay loams are dried out by the action of the clay loams. Moisture suctions higher than 5 and sometimes higher than 7 atm are found in the upper layer of the clay loams, so that there is a large moisture gradient between the upper layer of clay loam and the sand layer over it. At a depth of 1 m, the moisture suction reaches 5-7 atm, but in the deeper root zone it does not exceed 3 atm and, below 1.5, 1 atm. In the surface 30 cm sand layer, which is penetrated with roots, the moisture suction did not exceed 0.5 atm during the year, except for two short periods in August and September. Moisture suction values also give much better comparisons between sandy and two-layered soils (clay loam with sandy overburden) than do single moisture contents. They revealed that the sandy surface layers under mixed pine and beech plantations have more available moisture than do the surface layers of the deep sandy soils under pine and beech. In the clay loam under sandy overburden, greater depletion of the loosely bound water occurs than in the sandy soils at the same depth (about 0.5-1.0 m). At the same time, the layers below 1.5 m always contain sufficient available moisture in both sandy and clay loam soils.

Determinations of field capacity (more exactly, spring moisture), summer drying (compared with wilting moisture), and observations on the penetration of rain into the soil were carried out in order to study the sufficiency of moisture for plantings. These investigations gave the following results.

The moisture contents in the spring of 1954 were low because of low precipitation during the winter, but in 1955 it was normal. In the fine sands studied, the moisture content was about 10 volume percent, but in the upper layers it sometimes rose considerably higher (to 30%) depending on the humus content. Upon com-

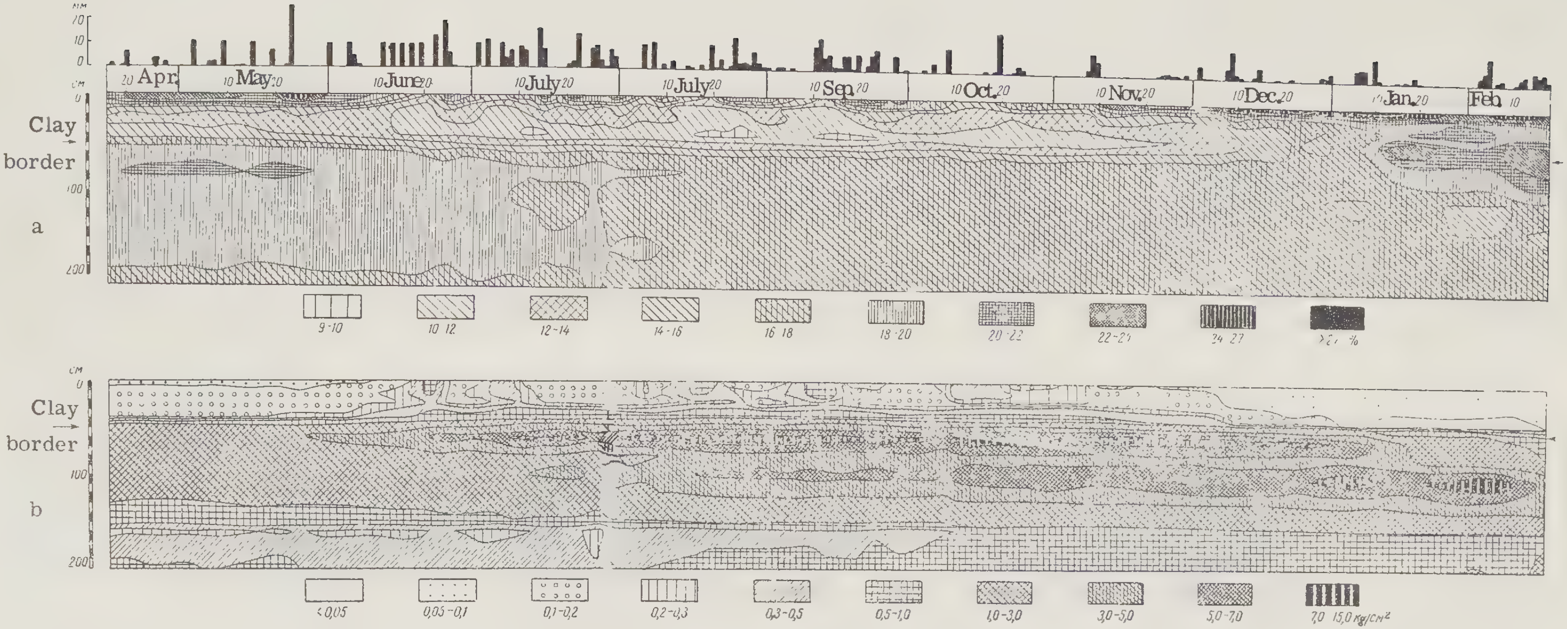

Fig. 3. - Chrono-isopleths of soil moisture from electrical conductivity measurements on sardy soil 50 cm thick over morainic clay loam (quadrat 34).

A - Volume percent of soil moisture; B - Moisture suction (kg/cm^2).

paring these values with moisture contents at given moisture suctions, it was clear that the spring moisture was held with a moisture suction of 0.1 atm, but in surface layers rich in humus, 0.1-0.2 atm (Fig. 4, A). In the medium sands, the moisture suction was lower, less than 0.05 atm in the soil and somewhat higher than 0.05 atm in the upper humus layer. In the clay loam, the spring moisture was held with a moisture suction of about 0.3 atm (Fig. 4, B). Attention is called to the lower moisture contents sometimes observed in the spring in deeper layers of sand.

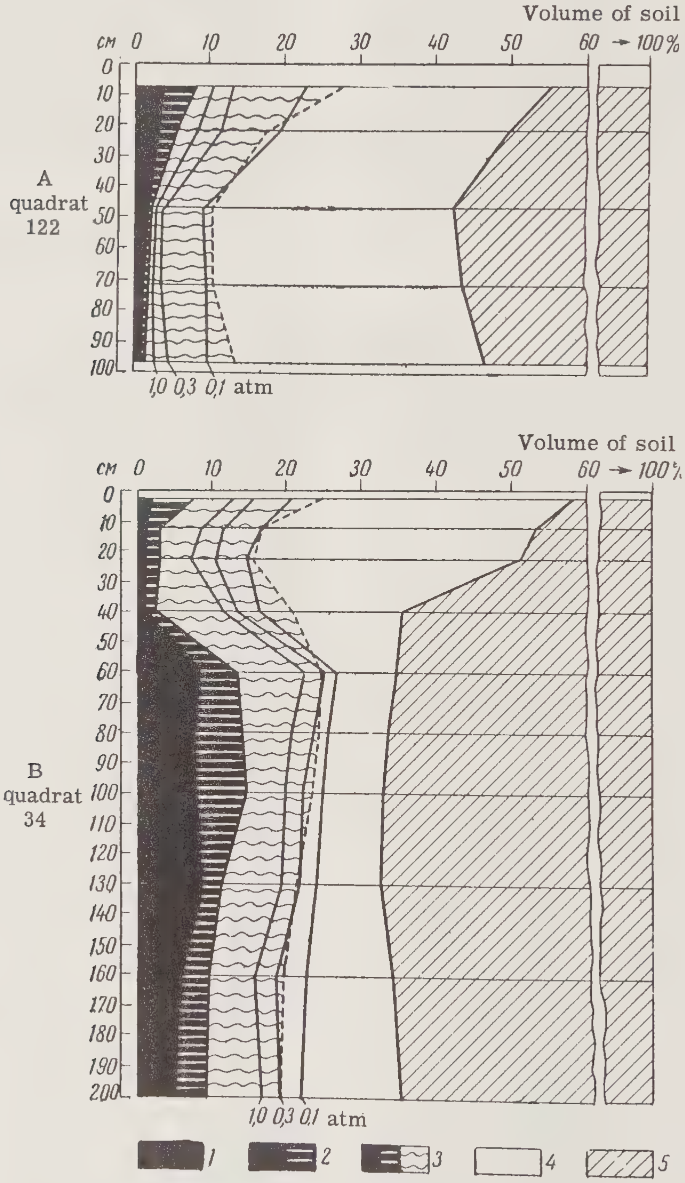

Fig. 4. - Volume relationships in soils:

A - sandy, 100 cm thick; B - sandy, 50 cm thick over morainic clay loam. 1 - hygroscopic moisture with suction >50 atm; 2 - non-available moisture with suction >15 atm; 3 - spring moisture. For comparison, lines corresponding to moisture suction values of 0.1, 0.3, and 1.0 atm; are shown; 4 - soil air; 5 - soil particles.

Wilting moisture determinations with different plants give quite widely varying results with he same soil. Pine seedlings were especially useful plants for the experiments. Different stages of wilting could be distinguished by the curvature of non-lignified parts. The moisure content in the soil at a moderate stage of wilting of pine seedlings corresponds to 15 atm moisture suction as determined with the moisure suction apparatus of Richards (1). In the ine sandy soils studied, this moisture content s about 1.5-2.5 times higher than the hygroscopic moisture by Mitscherlich's method. Moisture contents close to wilting, as has already been pointed out, were observed in the summers of 1954 and 1955 in the uppermost ayer of the medium sandy soils, and only those under beech and pine-bilberry did not undergo extreme drying.

We paid special attention to the infiltration of water into sandy soils. Three types of infiltration were distinguished: 1) rapid iniltration following summer drying; 2) rapid nfiltration at high moisture contents in the winter and spring; and 3) slow transfer of ree water at moderate moisture contents and ow moisture suctions, especially clearly observed in the spring and in deep soil layers. nfiltration of water into soil following summer drying was observed with natural rainfall as well as artificial irrigation. Soil darkening was observed on the section walls after moistening, and moisture contents were determined in them. This revealed the following.

Summer rains following a dry period infilrate into sandy soils under pine with a mor ype litter and coarse humus only in "tongues." These moistened "tongues" become shorter and harper under thicker forest litter. The case f pine forest with common hairgrass ground cover on fine and medium sands may be pointed ut as an example (Fig. 5, A). Sixty hours after a shower of 25.8 mm, the soil moisture in most laces was 3%-6%. Individual moistened tongues eaching a 60 cm depth had up to 10%-20% moisure.

Rains infiltrate more readily into the soil under pine-beech plantations with favorable humus tatus. For example, in the sandy loam over lay loam (with a ground cover of mull-type mor nd barberry), moisture infiltrated 20 cm from he surface and 30 cm in places, after 12 hours Fig. 5, C). An intermediate position was ocupied by the pure beech plantations on fine sand with a somewhat less decomposed litter. Alhough moisture infiltration here also occurred mainly in "tongues," it was on a larger scale han under pine. After three days, the entire upper part of the soil was moistened, although ot uniformly.

The moistening of a coarse sandy podzolized rown earth with grass cover is very interesting (Fig. 5, B). Rains soaked into it through the A_1 horizon, which is rich in humus from grass roots and probably not easily moistened. At separate points, the moisture is distributed over a broader front. Three days after the start of wetting, the A_1 horizon was still dry in many places, while the B horizon was moistened throughout to a depth of 30 cm. Individual broad "tongues" penetrated even deeper.

Thus, it appears that humus status very strongly affects the infiltration of summer rains into sandy soils. Tongue-like infiltration, which is long- and well-known with respect to more or less dried clay loam soils, apparently is also common with sandy soils under forest.

Infiltration of water into moist soils was studied in the spring by using NaCl applied to snow or soil. In the latter case, after application of the NaCl, an artificial irrigation of 25 mm was carried out. One day later the soil was excavated, the depth of water infiltration was noted, and the Cl ion concentration in soil samples was determined. Here also tongue-like infiltration of moisture predominated. The medium and fine sandy soils under pine with a ground cover of grasses and green moss will serve as examples. In Figure 6, Cl ion concentration is denoted by the size of the points. Experiments with NaCl carried out on snow gave similar results. This may be influenced somewhat by uneven melting of the snow.

The slow movement of water into deep soil layers is very clearly demonstrated by the chrono-isopleths derived from conductivity measurements. For example we present the fine sand under beech investigated in the spring of 1956 (Fig. 7). At the beginning of March, its water content was still quite low (about 7% at a depth of 2.5 m). From March 7 to April 11, it increased to about 9%, probably because of rainfall, although March was very dry. Not until the beginning of May did the moisture increase to 10.5%. Such slow moisture movement has not been observed in sandy soils before now.

Finally, we will mention the studies which began in 1956, carried out on substances added to soil and nutrient cycles in the mixed plantations of pine and beech on clay sands overlying glacial clay loam. A few results of these studies, carried out by W. Schulz, may be summarized as follows: of the total of 367 mm of precipitation (average for a 2 year period) from the end of May to the beginning of December, the crowns retained 136 mm (37%), and 17 mm (5%) flowed down on the trunks, mainly of beech (more than 200 l.).

In the previously mentioned time intervals, 10.0 kg CaO and 2.6 kg K_2O were added to the soil in open areas by precipitation. Under trees, 23 kg CaO and 12 kg K_2O were added.

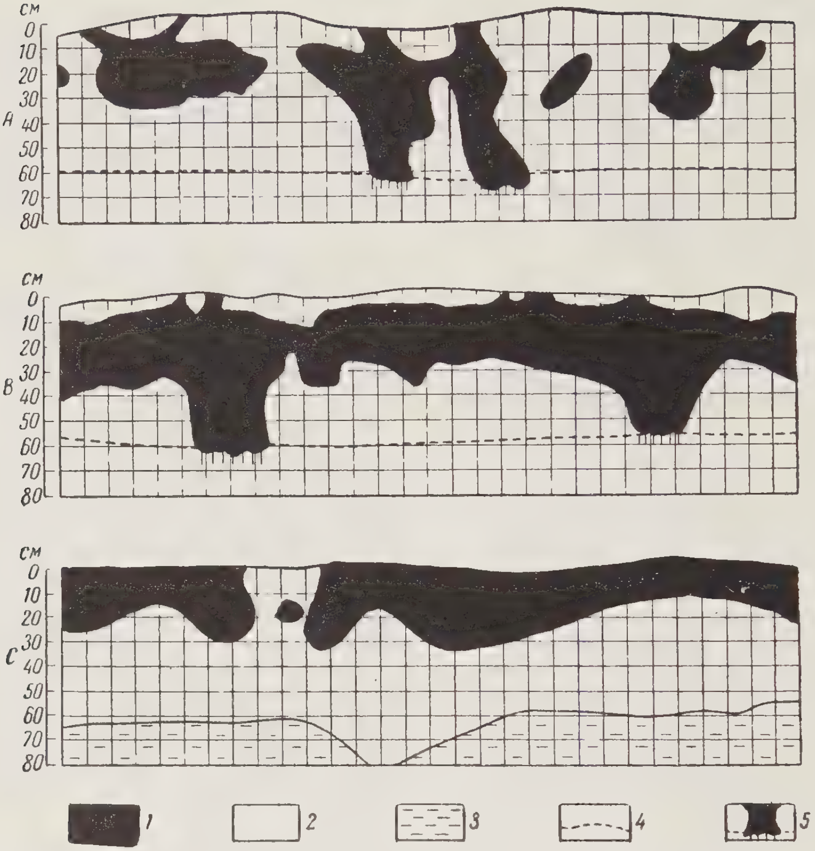

Fig. 5. - Water infiltration into soils after a summer shower of 25.8 mm.

A - sandy soil under pine and common hairgrass (quadrat 85) 60 hours after the rainfall; B - gravelly coarse to medium sand under sparse pine stand with grass vegetation (quadrat 35) 70 hours after the rainfall; C - sandy soil about 60 cm thick over morainic clay loam under mixed pine-beech stand (quadrat 34) 12 hours after the rainfall. 1 - "tongues" of infiltrating water; 2 - non-moistened part of the sandy soil; 3 - morainic clay loam; 4 - border between the upper soil layer, which dries out during the summer, and the wetter subsoil; 5 - places where tongues reached the moist subsoil and penetrated deeper.

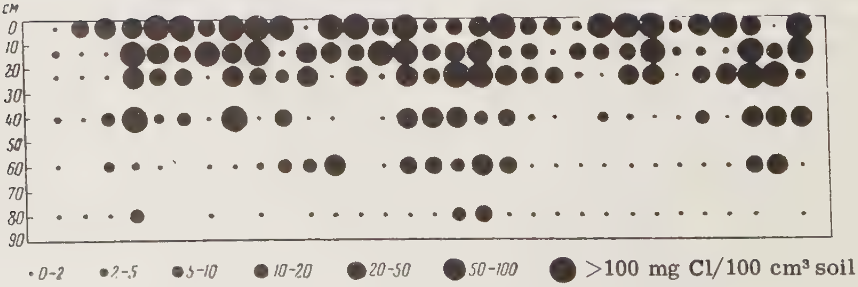

Fig. 6. - Water infiltration into a sandy soil under pine with a ground cover of common hairgrass (quadrat 85) in the spring at full moisture saturation (from Cl ion concentration 24 hours after artificial irrigation with a 2.4% NaCl solution).

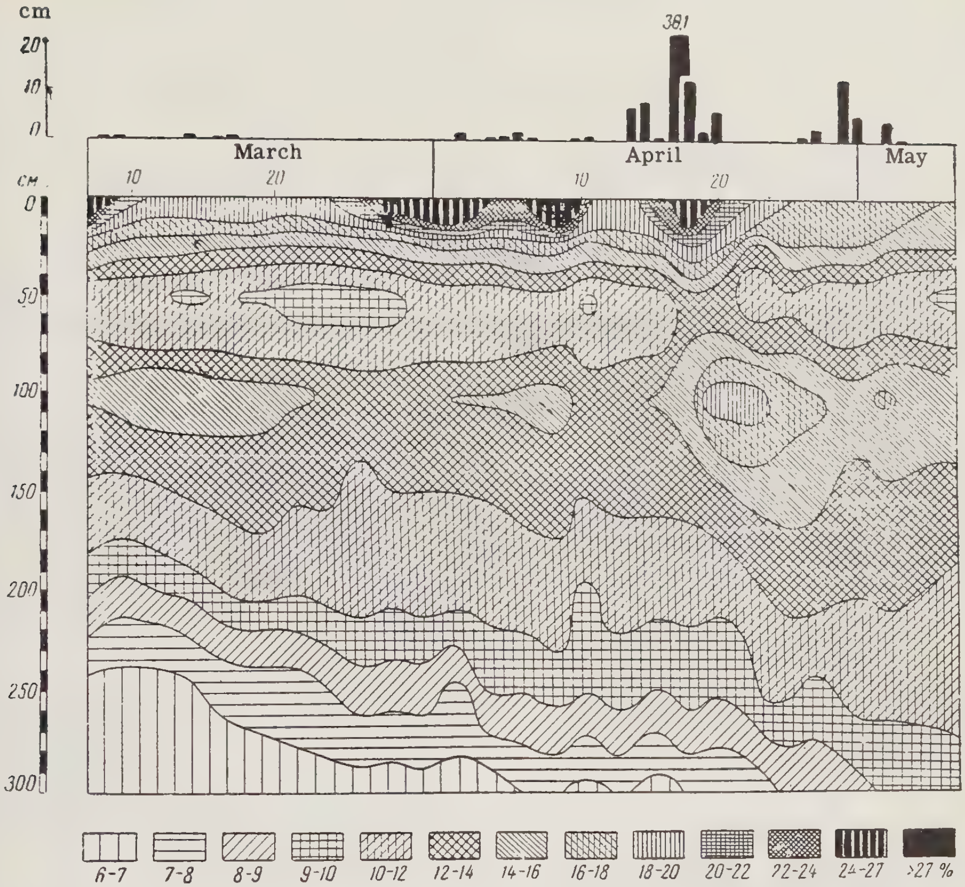

Fig. 7. - Chrono-isopleths of soil moisture in volume percent from electrical conductivity measurements on sandy soil, Finoftal (quadrat 122):

his shows very significant leaching of calcium nd especially potassium from leaves. The pH alues of water running down tree trunks were ery low, 2.7 on pine (extreme limit 2.1) and .2 on beech.

In order to study the chemical composition f leaching water, we used lysimeters, consistng of 50 x 50 cm pans, receivers, and pipes r emptying (according to Shilova). The lysieters were placed in the soil in its natural ondition.

Almost the entire amount of precipitation ppeared under fresh litter (A_0' horizon), and nly about half of it under the A_0''' and A_1 horions. Water appeared under the A_0''' horizon nly with precipitations of more than 5 mm. ater infiltrated frequently through the A_1 horion, but very rarely through the B horizon. ater was found more often directly over the ay loam.

These investigations were supplemented by determinations of the chemical composition of the leaching water, and also by data on the amounts of mineral elements in the rain. All of these results enable interpretations to be made of features of the water and nutrient regimes, and of soil formation for locations with mixed plantations.

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CONTRIBUTION TO THE TECHNIQUE OF SOIL STRUCTURE STUDIES[1]

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Soil aggregate analysis still has a number of unsolved problems, for example: a) the method of taking soil samples in the field; b) their preparation for aggregate analysis; c) the period of sample storage between their collection in the field and analysis; d) the method of wetting aggregates with water; e) the temperature of the water used when sieving samples under water; f) the period of seiving samples in the air-dry state; g) the preparation of representative samples for analysis; etc. In addition, aggregate analysis has a great deal of subjectivity and its results are compared with difficulty.

The Soil Science Department of the High School of Agriculture and Forestry at Brno carries out studies on soil aggregation and conducts tests to develop methods of aggregate analysis which are simple and rapid, and adapted to carrying out large numbers of analyses.

In this paper we present briefly the experimental results obtained using representative samples taken in the usual way and composited from separate fractions from the aggregate analysis of dry samples by the method of V. Novak and M. S. Tsyganov. In addition, we determined the effect of different methods of wetting for aggregate analysis by Novak's method.

Experimental

Effect of Method of Preparing Representative Samples. Two methods of preparing representative samples were used for aggregate analyses.

According to some methods (V. Novak, A. F. Tyulin, G. I. Pavlov), a representative sample may be taken in the ordinary way, as for chemical and particle-size analysis. Such preparation is quick and simple. According to other methods (N. I. Savvinov, M. S. Tsyganov, et al.), it is necessary to carry out a preliminary dry aggregate analysis and composite the sample for wet analysis by weighing out 1/2 portions of the percentage of each fraction obtained. Such preparation is tedious, injurious to health because of dustiness during sieving, and is quite subjective if used without appropriate mechanical apparatus.

In the Czechoslovakian Republic, Tsyganov's method is recommended for studying the effect of grass-arable systems on soil aggregation, and many analyses have been carried out using it. In the Soil Science Department of Brno Agricultural High School, Novak's method is used more frequently, chiefly because the amounts of microaggregates with diameters down to 0.01 mm can be determined.

In Novak's method, a 50 g representative soil sample is prepared in the ordinary way, soaked for 24 hours in distilled water (1 part soil: 3 parts water), and then sieved under water through an assembly of sieves with openings of 2.0, 1.0, and 0.5 mm diameter. The sieves are slowly moved up and down under water as long as the aggregates are sieved.

The material passing through the sieve with openings of 0.5 mm diameter is transferred without breaking into the narrowest cylinder of the Kopetsky apparatus, in which further separation of the aggregate fractions is carried out. Seven aggregate fractions are obtained using this method, with diameters >2, 2-1, 1-0.5, 0.5-0.1, 0.1-0.05, 0.05-0.01, and <0.01 mm.

Novak's method has a second modification, in which the 50 g representative sample is moistened for one hour by capillarity on filter paper. Then the soil is washed onto the sieve assembly and sieved under water. The further procedure of the analysis is the same as in the first modification.

Results obtained by the two methods of preparing representative samples were compared

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[1] Presented at the First Delegate Congress of Soil Scientists, May, 1958.

Table 1

Aggregate analysis according to Novak's method, percent

Sample[a]	Aggregate diameter, mm						
	< 0.01	0.01–0.05	0.05–0.1	0.1–0.5	0.5–1.0	1.0–2.0	>2.0
Chernozem on loess, A horiz. a)	11.4	15.3	20.9	21.8	15.7	7.0	7.9
b)	8.9	18.2	21.9	21.0	13.9	7.2	8.9
Loess a)	11.1	26.0	26.1	26.8	6.2	1.8	2.0
b)	10.9	25.1	26.2	29.7	5.0	1.9	1.2
Brown earth on Permian shale, A horizon, Ivanchitse a)	12.3	18.4	16.9	22.6	15.4	6.0	8.4
b)	12.5	18.4	14.9	20.3	16.2	7.4	10.3
Brown earth on loess, A horizon, Brno A a)	12.4	27.9	22.2	22.9	6.5	3.2	4.9
b)	10.7	26.4	22.6	21.1	10.2	4.4	4.6
Brown earth on loess, B horiz. a)	10.3	21.9	13.6	17.1	20.5	10.1	6.5
b)	10.3	15.8	13.9	16.8	24.7	10.7	7.8
Rendzina on marl, A horizon a)	11.3	11.2	13.6	16.5	22.4	13.2	11.8
b)	10.6	11.1	13.2	15.6	23.4	10.5	15.6

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[a] a) — representative sample prepared in the usual way; b) — representative sample composited from separate fractions.

o determine their effect on the aggregate an-
lysis. For this purpose, soil samples were
aken differing from each other in texture,
ontent of $CaCO_3$ and humus, and degree of
ase saturation. Duplicate analyses were run
n all samples. In case of large discrepancies,
 third analysis was carried out.

The results of aggregate analyses carried
ut by Novak's method are presented in Table
. The representative samples were prepared
 the ordinary way, and by compositing from
eparate fractions obtained by sieving through
ieves with openings 5, 3, 2, 1, 0.5 and 0.25 mm
 diameter.

These results are practically identical. Con-
equently, there is no need to composite rep-
esentative samples from separate fractions
or aggregate analysis by Novak's method. It
 quite sufficient to weigh out the representa-
ve sample in the ordinary way.

The results presented in Table 2 were ob-
ined by Tsyganov's method.

With this method also, the method of pre-
aring the representative sample showed no
fect on the aggregate analysis. Although
omewhat larger differences are observed be-
veen methods of preparation, they are within
e limits of acceptable error.

The results of aggregate analyses by Novak's
d Tsyganov's methods are compared in Table
 These methods determine different aggregate fractions, so that only three fractions (>1, 1-0.5, and <0.5 mm in diameter) are compared.

In Novak's method, a representative sample prepared in the ordinary way was used, and the aggregates were moistened by capillarity for one hour (value a). In Tsyganov's method, a representative sample was composited from separate fractions, and the aggregates were also moistened by capillarity for a period of one hour (value b).

In this case also, the results were very close, especially for soils in which the larger aggregates were less stable. The variation was mainly 5%-10%, which is considered quite permissible, taking into account the subjectivity of aggregate analysis.

Effect of Different Methods of Moistening Aggregates. Before analysis it is necessary to moisten the aggregates and displace the air from them. Two methods are used:

1) Immersion in water. The aggregates are plunged into a cylinder filled with water. Hereby, most of the air in the internal pores of the aggregates is rapidly displaced. The remaining air is expelled by repeated inversions of the cylinder or by long submersion in water (Novak). In this way, a greater disruption of aggregates occurs, corresponding to natural conditions in sudden showers, when rapid moistening of aggregates occurs on the surface of the plow layer.

Table 2

Aggregate analysis according to Tsyganov's method, percent

Sample[a]		Aggregate diameter, mm			
		<0.25	0.25–0.5	0.5–1.0	>1.0
Chernozem on loess, A horizon, Ivanchitse	a)	33.0	14.3	29.3	27.4
	b)	37.7	16.3	25.3	24.7
Chernozem on loess, A horizon, Lednitse	a)	51.5	18.4	25.0	8.1
	b)	53.3	19.6	22.7	7.3
Brown earth on Permian shale, A horizon, Ivanchitse	a)	33.4	17.0	32.2	20.3
	b)	38.5	16.5	27.9	20.0
Brown earth on loess, A horizon, Brno	a)	32.4	16.7	37.7	15.1
	b)	34.8	20.8	33.9	12.4
Brown earth on loess, B horizon, Brno	a)	32.2	13.4	32.7	25.6
	b)	37.4	12.1	27.6	26.9
Alluvium, plow layer, Zhabchitse	a)	20.3	10.8	18.1	55.8
	b)	18.0	8.2	21.8	58.1

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[a] a) — representative sample prepared in the usual way; b) — representative sample composited from separate fractions.

Table 3

Aggregate analysis according to the methods of Novak and Tsyganov, percent

Sample		Aggregate diameter, mm		
		>1.0	1.0–0.5	<0.5
Chernozem on loess, A horizon, Ivanchitse	a)	25.3	24.6	50.1
	b)	25.4	27.3	47.3
Loess, Brno	a)	9.5	23.9	66.6
	b)	11.9	29.6	58.5
Brown earth on Permian shale, A horizon, Ivanchitse	a)	22.2	26.7	51.1
	b)	24.4	28.8	46.8
Brown earth on loess, A horizon, Tishnov	a)	12.9	23.7	63.4
	b)	14.4	27.6	58.0
Brown earth on loess, B horizon, Tishnov	a)	45.7	24.1	30.2
	b)	50.2	22.7	27.1
Rendzina on marl, A horizon, Brno	a)	45.2	25.4	29.4
	b)	51.8	22.1	26.1

This method affects the condition of aggregates considerably, but the results indicate the maximum water stability of aggregates, as was previously stressed.

2) Capillary saturation. This method consists of gradually moistening the aggregates with a capillary source of water, which prevents the sudden bursting of aggregates with

air. Capillary saturation corresponds to those natural conditions which arise upon saturation of aggregates with capillary moisture from the subsoil.

Different investigators recommend different times of capillary saturation. Most Soviet soil scientists recommend one half-hour. For Czechoslovakian soils, according to studies by G. Tyaglo, one half-hour appears insufficient for capillary saturation. This idea is supported by the fact that with longer periods of saturation aggregates continued to disintegrate, as a result of which the water became turbid. Thus, for our conditions, we recommend lengthening the time of capillary saturation to one hour.

The effect of different methods of moistening aggregates on the aggregate analysis are seen in Table 4. Here are presented data obtained by Novak's method with 24 hours of soaking in standing water (value a), and with capillary saturation through moist filter paper for one hour (value b).

Chernozem soils developed on loess were used. They are characterized by very coarse texture, low humus content, considerable carbonates, and very low water stable aggregates. In addition, examples of alluvial soils characterized by clay texture and considerable structure stability are presented in Table 4. It appears that the method of saturation greatly affects the aggregate analysis, both in soils with low aggregate stability and those distinguished by stable structure.

The most conspicuous differences were observed in the contents of the >2 mm diameter fraction. From this it follows that capillary saturation, even for one hour, is insufficient to break down coarse aggregates. In some cases, the results are extremely high and have no reality.

The greater breakdown of macroaggregates under 24 hours soaking always gave an increased percentage of microaggregates in the fractions 0.01-0.05 and 0.05-0.1 mm in diameter.

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Table 4

Aggregate analysis according to Novak's method, percent

Sample number, depth, and soil		Aggregate diameter, mm						
		<0.01	0.01–0.05	0.05–0.1	0.1–0.5	0.5—1.0	1.0—2.0	>2.0
1, 10—20 cm, chernozem on loess	a)	12.6	27.3	31.6	21.9	4.2	1.0	1.4
	b)	11.4	18.6	21.3	28.6	11.0	1.9	7.2
39, 10—20 cm, chernozem on loess and sand	a)	12.0	19.0	26.8	32.9	5.6	1.4	2.3
	b)	10.1	13.9	15.2	34.2	15.3	3.1	8.2
48, 10—20 cm, alluvium	a)	9.9	11.0	20.4	46.1	8.8	1.6	2.2
	b)	10.6	6.1	13.0	39.4	12.4	2.8	18.7
64, 10—20 cm, chernozem on loess and sand	a)	11.9	24.8	28.1	24.6	6.2	0.8	3.6
	b)	6.8	10.9	13.6	28.9	13.5	4.2	22.1
75, 10—20 cm, clay alluvium, gleyed	a)	8.4	8.5	13.9	29.1	11.5	17.9	10.7
	b)	9.0	0.3	1.9	7.5	8.8	11.7	60.8
80, 10—20 cm, clay alluvium, gleyed	a)	9.6	7.3	12.8	31.1	19.2	17.5	2.5
	b)	23.9	0.7	1.3	5.9	14.2	13.4	40.6
90, 10—20 cm, clay alluvium, gleyed	a)	8.0	1.7	2.8	8.1	17.2	32.1	30.1
	b)	8.3	1.2	2.0	5.4	13.6	24.6	44.9
98, 10—20 cm, chernozem on loess	a)	26.5	4.6	7.2	14.4	14.4	14.3	18.6
	b)	5.9	1.0	2.9	7.9	10.3	15.1	58.9

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THE EFFECT OF TWO-LAYERED ALLUVIUM ON THE WATER REGIME OF THICK CHERNOZEMS[1]

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A. F. Lebedev (6) first showed that when a coarse-porous deposit underlies a fine-porous soil, there is a certain amount of moisture held above the contact between these two layers in addition to moisture that would be held by the upper layer if it were underlain by a thickness of the same material. Moisture held in this way was called suspended capillary moisture by Lebedev. Properties of this moisture were further studied by Staprens (9), but the studies of both Lebedev and Staprens were of a laboratory nature. This phenomenon has not been studied under natural conditions, although the above-mentioned soil formations are widely distributed.

In this article, we shall discuss a concrete example of the water regime in a two-layered soil formation. Such an example is furnished by the thick chernozem of the Central Chernozem Game Reservation in Kursk Oblast'. From personal communications of Afanas'yeva and the article of Firsova (10), it is known that a soil-forming alluvium with a uniformly thick upper layer is widely distributed in the northern and central part of the Central Russian Upland.

The parent material in the Central Chernozem Game Reservation has the following composition: from the surface to a depth of about two meters (ranging from 190-250 cm) is a fine silty clay loam, in which is developed a humus horizon about 90 cm thick and the upper part of a calcareous horizon. The fine clay loam is underlain by a coarser, pale yellow silty clay loam. The boundary between these layers is clearly defined. The upper fine clay loam covers all elements of the relief with a layer of uniform thickness. Particle-size analysis (Table 1) show that these so-called clay loams differ greatly from each other.

Soil moisture observations show that more moisture is held in the layer of fine clay loam lying directly over the contact with a coarse clay loam than the minimum moisture capacity (MMC) of the upper clay. As Lebedev explained, the moisture is held by surface tension. Our observations show that accumulation of moisture exceeding the MMC begins above the contact of the two layers, but during subsequent moisture movement it is distributed vertically throughout the entire two meter thickness of fine clay loam.

Moisture distribution in a virgin steppe soil is illustrated in Figure 1 at the times of maximum content in the spring (May 5, 1953), two weeks later (May 20), a month later (June 4), and at the driest time — the end of the growing season (September 9). In addition, the curve of moisture values corresponding to the experimentally determined MMC is drawn.

The figure shows that, in the spring, a considerable quantity of moisture exceeding the MMC was held above the contact of the two layers. Excess moisture was observed in the entire thickness of fine clay loam, but mostly in a layer about 70 cm thick lying 140-210 cm from the surface. The total excess above the MMC was 65 mm. Of this, 32 mm was located in the lower 70 cm.

In the example described, the distribution of excess moisture, especially on June 4, has the same character as that in Staprens' experiments (9). The maximum thickness of the layer with suspended capillary moisture (according to Staprens) is equal to the difference between the capillary rises characteristic of the upper and lower layers. The upper part of the moisture distribution curve in the layer with suspended capillary moisture appears to be the normal capillary curve characteristic for this layer. Staprens concluded that this was apparently correct only for the sandy deposits with which he experimented.

In clay loam deposits of this type, water is distributed only during the initial wetting and

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[1] This article is written from material obtained in a tudy of the water regime in thick chernozems at the Central Chernozem Game Reservation from 1946 to 953.

Table 1

Particle size distribution in the two-layer alluvium of Profile 2 of Ye. A. Afanas'yeva (2), % of the ignited weight

Alluvium	Depth, cm	Particle diameter, mm						Total of fractions less than 0.0063
		>0.25	0.25-0.0063 by difference	0.0063—0.002	0,002—0,00063	0,00063—0,0002	<0,0002	
I	140—150	None	60.43	9.30	4.34	2.89	23.04	39.57
	190—200	None	56.63	9.83	4.52	6.81	22.21	43.37
II	220—230	0.03	81.38	3.30	0.82	None	14.50	18.62
	240—250	None	82.36	2.64	0.51	1.98	12.51	17.64

Note: The analysis was carried out by Ye. A. Afanas'yeva by the pipette method, with preliminary Na saturation according to Gedroyts. Carbonates were destroyed by treatment with 0.005 N HCl. An amount of acid was used equivalent to the carbonate content. After removal of the carbonates, the soil was saturated with Na, then washed with alcohol to free it of NaCl.

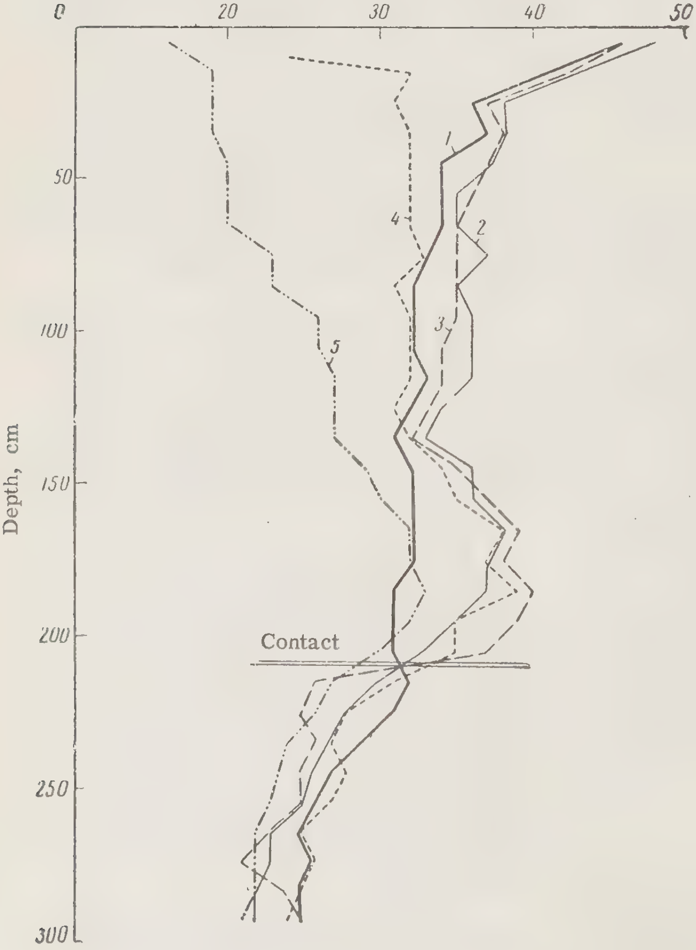

Fig. 1. - Changes in soil moisture under steppe in 1953, percent of volume.

1 - Minimum moisture capacity. Soil moisture; 2 - May 5; 3 - May 20; 4 - June 4; 5 - Sept. 9.

after the water exceeding the MMC has been used. When much water is held above the contact, it serves as a water barrier for the overlying clay loam layer.

The course of this phenomenon appears to be as follows. With surface additions of moisture, the entire thickness of fine clay loam is first moistened to the MMC. Further surface additions produce an accumulation of moisture above the contact of the two-layer alluvium. Therefore we could not determine the MMC by ordinary methods. High results are always obtained above the contact of two different layers. Further additions of moisture do not increase the moisture content in the lower part of the fine clay loam, but gradually increase its content in the entire two meter thickness. At maximum moistening, the increase above the MMC is quite uniform throughout the entire thickness of fine clay loam. Calculations showed that this increase in cultivated chernozem in forest-glade amounted to a total of 70 mm in 1948 and 100 in 1951, in chernozem under forest to 117 mm in 1948, 80 in 1951, and 110 in 1953, and in steppe chernozem to 65 mm in 1953.

We now consider one of these examples. The moisture distribution in a cultivated thick chernozem in forest-glade is illustrated in Figure 2 for the period of maximum moisture content and the subsequent drying out. In 1951, because of exceptionally high rainfall in May (163 mm), the soil reached maximum moisture content at the end of May and beginning of June. The moisture content curves show that on June 1 the entire depth of fine clay loam contained moisture significantly exceeding the MMC. In the lower half of the fine clay loam, the excess averaged 6.8% of the soil volume and varied little with the profile. In the upper meter, the excess was not as great, averaging 3.6% of the soil volume. The lower moisture content in the upper part of the soil might be explained by uptake of moisture through plant roots.

Excess moisture content above the MMC is also noted in the upper part of the coarse clay loam and will be considered below, but first we will consider changes in moisture content in the fine clay loam layer.

The moisture content decreased uniformly in

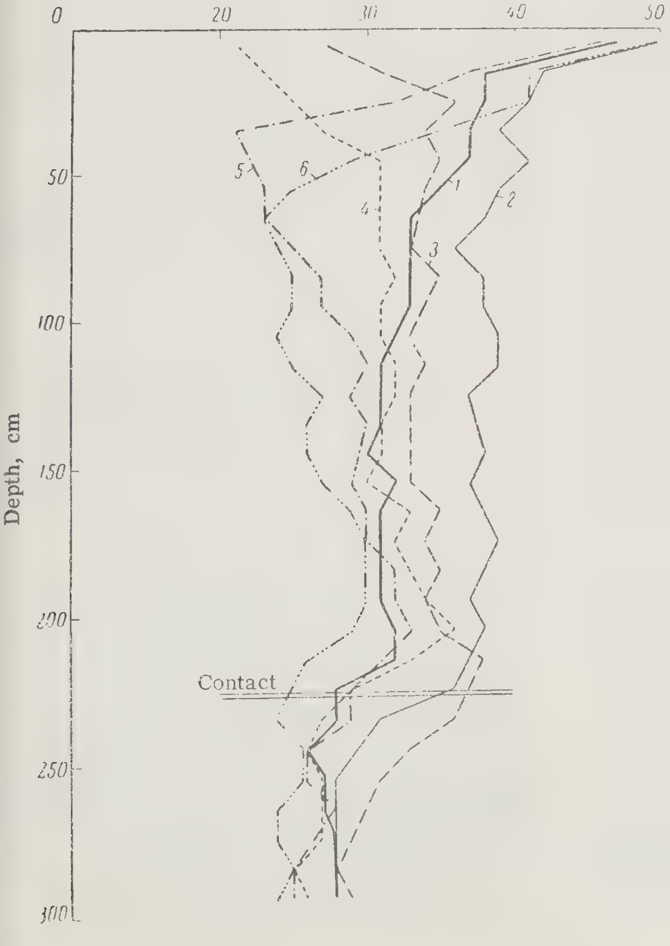

Fig. 2. - Changes in soil moisture in forest-glade in 1951, percent of volume.

1 - Minimum moisture capacity. Soil moisture; 2 - June 1; 3 - June 19; 4 - July 4; 5 - August 4; 6 - September 1.

the entire thickness of fine clay loam from June 1 to 19, with the total loss amounting to 95 mm. Such a uniform decrease in moisture supply could result from drainage of gravitational water or from ascent in the liquid form to the place of utilization — the horizon of maximum plant root development. Changes in moisture content were visible in the entire 3.5 meter thickness of soil, but moisture moved in two directions and in different magnitudes. In this period of time, the moisture content in the upper 1-1/2 meters of underlying coarse clay loam (200-350 cm from the surface) increased by 33 mm, but the remaining two-thirds — 62 mm — could have been removed only by ascent. If the moisture were removed in place by uptake through plant roots, such uniform removal would not be possible.

From June 19 to July 4, moisture was utilized from the entire depth of moist soil. At the end of this period, the moisture distribution in the soil profile had the following character. Drying out was greatest in the upper part of the humus horizon because of moisture absorption by plant roots. The amount of moisture remaining here was lower than the MMC. In the lower and greater part of the fine clay loam, including the lower part of the humus horizon and the upper part of the carbonate horizon, the moisture content decreased only to the MMC, while the lower 60 cm of the fine clay loam contained moisture exceeding the MMC. In the upper part of the coarse clay loam, as in the greater part of the overlying fine clay loam, the moisture content decreased to the MMC. In the entire soil profile, except the layer 160-220 cm from the surface, the moisture exceeding the MMC had disappeared. At the same time, moisture had not penetrated into the deeper layers of the coarse clay loam. The moisture content in the layer 300-350 cm from the surface did not change significantly during the entire growing period. It was: May 9, 130 mm; May 17, 127 mm; June 1, 117 mm(?); June 19, 131 mm; July 4, 128 mm; July 16, 128 mm; and August 6, 130 mm. This leads to the supposition that liquid moisture moved from the upper parts of the coarse clay loam into the fine clay loam and was utilized for transpiration.

After July 4, the character of moisture utilization changed. Appreciable quantities of moisture were used only from the upper meter. The amount used decreased with depth, which is characteristic for moisture use between the MMC and the content at which capillary films are broken. In the upper 30 cm layer, the picture is complicated by moisture replenishment through rainfall. (Table 2).

In 1948 and 1951 under forest, and in 1951 under forest-glade (Fig. 2), the spring moisture penetrated into the underlying coarse clay loam. In all cases the amount of moisture held in the fine clay loam exceeded the MMC by about 100 mm. One may suppose that an excess of the order of 100 mm above the MMC is a moisture limit for fine clay loam. In other words, the two-meter thickness of fine clay loam has a moisture holding capacity of 775 mm instead of 675 mm, which corresponds to the MMC.

It may be asked how this value should be considered. Is it possible that 775 mm of moisture is the MMC value for the two-meter thickness of fine clay loam, and the experimentally determined MMC value is underestimated?

We have carried out the following work to resolve this question. From data for all the years of observation, moisture values were chosen for the cases when the soil was wet to a depth less than the thickness of fine clay loam in order to establish the maximum moisture retention by the soil, uncomplicated by the effects of differences in alluvia. In all the years of observation, nine such cases were established in the spring for steppe soils, nine for soils under forest, and five for soils in forest-glade. Examination of the data showed that the MMC values obtained in this way for steppe soils agreed very well with those determined experimentally (Table 3). Considerable discrepancy was noted in the humus horizon of soils under forest, especially in the upper 50 cm. This is apparently explained by the fact that, in determining the MMC on a flooded area under forest, the tree roots took up moisture in the ten days between wetting the soil and determining the MMC. This was not observed under steppe because the sod was removed from the flooded area, and both the flooded area and the adjacent vegetated area were covered to prevent evaporation. This eliminated removal by plants. The values obtained in this way appear to be the MMC of the soils studied.

The 100 mm of water exceeding the MMC, that is held in the upper two-meter thickness (as seen in Figure 2 and Table 2), has several properties affecting its utilization. This moisture is lost quickly and uniformly from the entire depth of fine clay loam to a value corresponding to the MMC.

It is known that the rise of liquid water in soils moistened to the MMC has a different character. The tension brought about by utilization of moisture from the upper layer decreases with depth and extends to one meter from the surface. Deeper moisture, at contents equal to the MMC, may be utilized only by absorption through roots entering such depths. A plot of total moisture utilization against depth for a soil moistened to the MMC gives a triangular figure with one apex extended, while that for a soil at maximum moisture lies almost vertical. Thus, moisture is utilized simultaneously from the entire thickness, as shown by the data in Table 2. Such vertical movement of moisture indicates that it occurs only by capillarity.

Table 2

Moisture utilization from the fine clay loam part of a thick chernozem in forest-glade at maximum and minimum moisture capacity, mm

Item	Observation date	Days	Depth, cm												
			0–5	5–10	10–20	20–30	30–40	40–50	0–50	50–60	60–70	70–80	80–90	90–100	50–100
Moisture, mm	June 1, 1951	—	29.8	20.2	42.0	41.0	39.2	41.0	213.0	39.4	38.1	38.0	37.8	37.9	191.0
	July 4, 1951	—	10.4	10.6	23.0	25.3	27.4	30.7	127.0	30.8	30.6	31.0	32.3	31.2	156.0
	Aug. 6, 1951	—	27.0	18.7	36.9	31.5	21.1	21.8	157.0	22.5	22.7	24.9	26.5	27.3	124.0
Moisture use with maximum moisture	June 1-July 4	33	19.4	9.6	19.0	15.7	11.8	10.3	86.0	8.6	7.5	4.0	5.5	6.7	35.0
Moisture use at MMC	July 4-Aug. 6	33	+16.6[a]	8.1[a]	+13.9[a]	+6.2[a]	6.3	8.9	+30.0[a]	8.3	7.9	6.1	5.8	3.9	32.0

Continuation of Table 2

Item	Observation date	Days	Depth, cm												
			100–110	110–120	120–130	130–140	140–150	100–150	150–160	160–170	170–180	180–190	190–200	150–200	0–200
Moisture, mm	June 1, 1951	—	39.1	39.3	37.3	37.3	38.0	191.0	38.1	38.2	38.9	37.7	37.1	190.0	785.0
	July 4, 1951	—	30.9	31.5	31.5	31.2	31.4	157.0	32.2	32.9	32.4	32.5	33.6	164.0	604.0
	Aug. 6, 1951	—	28.7	30.4	28.9	29.7	30.6	148.0	29.3	30.2	30.0	31.9	31.8	153.0	582.0
Moisture use with maximum moisture	June 1-July 4	33	8.2	7.8	5.8	6.1	6.6	34.0	5.9	5.3	6.5	5.2	3.5	26.0	181.0
Moisture use at MMC	July 4-Aug. 6	33	2.2	1.1	2.6	1.5	8.0	8.0	2.9	2.7	2.4	0.6	1.8	11.0	22.0

[a] High because of rainfall amounting to 56 mm between July 31 and August 8.

Moisture having such movement is related to suspended capillary moisture (8).

For a given case of changing alluvium, we tried to determine the maximum amount of moisture held as suspended capillary moisture. We determined this value from the moisture content in thick chernozem under forest at maximum spring moistening in the wettest years. Three cases with clearly developed suspended capillary moisture appeared in six years of observation: April 12, 1948, June 1, 1941, and April 13, 1953 (Table 4). The results agreed quite well. In the forest soils, except for the upper part of the humus horizon, the moisture content varied from 35%-37% of the soil volume (Table 4). In the two-meter thickness, the moisture content with suspended capillary moisture (PCM) averaged 70% of saturation.

Table 3

Minimum moisture capacity of thick chernozems determined in the field and experimentally, mm

Depth, cm	Under steppe		Under woods	
	From field data	Experimental	From field data	Experimental
0—5	29.3	26.3	26.3	28.1
5—10	17.9	20.1	17.8	18.7
10—20	39.4	41.2	37.5	31.4
20—30	35.7	36.2	38.2	32.4
30—40	35.8	37.1	36.6	32.2
40—50	33.8	34.2	36.7	33.7
50—60	33.4	34.0	35.3	33.2
60—70	32.6	33.5	33.3	31.9
70—80	33.2	32.6	32.7	31.4
80—90	31.1	31.7	33.2	33.8
90—100	31.4	32.0	33.2	32.5
100—110	31.2	32.2	31.7	31.9
110—120	30.9	32.5	31.7	31.4
120—130	29.8	30.2	31.3	31.4
130—140	29.3	31.0	30.7	30.9
140—150	31.1	31.9	31.1	30.2
150—160	31.3	32.1	32.0	31.7
160—170	32.8	32.1	31.8	30.6
170—180	32.3	32.0	32.0	31.1
180—190	33.5	31.0	31.8	29.2
190—200	32.0	30.6	29.3	30.7
200—210	31.8	31.3	31.6	31.2
210—220	28.0	31.6	—	31.6

Moisture utilization from the layer of fine clay loam, as will be seen by reviewing the soil moisture regime, proceeds in three successive stages.

First stage — utilization of suspended capillary moisture, exceeding the supply corresponding to the MMC. This moisture moves by capillarity to the place of its maximum utilization for transpiration.

Second stage — utilization of suspended capillary moisture, also by capillary rise to the place of utilization, between the points corresponding to the MMC and that at which capillary films are broken. This utilization is most strongly developed to a depth of about one meter from the surface, and in deeper horizons some moisture exceeding the capillary breaking point remains (Tables 3, 5).

Third stage — utilization of moisture in place by plant roots penetrating into the soil. Naturally, absorption by roots which penetrate the entire thickness of soil to different degrees, is superimposed upon moisture movement in the first two stages of utilization. Such superimposition of processes complicates the picture that might be observed if moisture were lost only by evaporation from the soil surface.

Table 4

Suspended capillary moisture in forested soils, mm

Depth, cm	Minimum moisture capacity	Suspended capillary moisture				Fully moisture saturated
		April 12, 1948	June 1, 1951	April 13, 1953	Average	
0—5	28	38	31	32	34	61
5—10	19	21	20	34	24	
10—20	38	43	41	49	44	55
20—30	38	44	43	45	44	57
30—40	37	42	41	46	43	54
40—50	37	42	41	44	42	55
50—60	35	40	39	43	41	54
60—70	33	37	37	37	37	54
70—80	33	37	35	38	37	53
80—90	34	39	36	37	37	53
90—100	34	38	35	35	36	53
100—110	32	39	35	34	36	53
110—120	31	39	37	35	37	53
120—130	31	36	35	34	35	53
130—140	31	35	37	33	35	51
140—150	30	35	37	33	35	49
150—160	32	35	37	35	36	48
160—170	31	38	39	34	37	46
170—180	31	38	38	35	37	45
180—190	31	38	35	36	36	43
190—200	31	38	32	36	35	43
200—210	32	38	30	36	35	43
210—220	32	37	32	34	35	43

With observations on the soil water regime, we must mention the soil moisture conditions corresponding to the changing stages of moisture utilization. For illustration we present the soil moisture changes under forests (Table 5). The thick chernozems always contain some available moisture, even with maximum drying out (in the third stage). Drying to the wilting moisture (WM) was noted only in virgin soils and only for very short times during droughts in 1946 and 1947 (4). Such drying extended only 10-20 cm from the surface.

From the foregoing it is apparent that the two-layered soil forming materials have great significance for the water supply of plants and for soil formation. In the described cases, two-layered alluvium made possible the accumulation of readily available and mobile suspended capillary moisture.

Vegetation on soils formed on uniform clay loams with deep ground water has only a supply of moderately available moisture, lying between the MMC and the capillary breaking point. In the described cases, the soils held up to 100 mm of easily available moisture in excess of the MMC.

The characteristic of the soil water regime, given by the two-layered alluvium, plays a large role in soil formation. Such regimes are significantly, if not primarily, associated with the formation of thick chernozems and a slight development of leaching in them. The rising flow of suspended moisture opposes the leaching of thick chernozems.

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Table 5

Moisture contents in thick forested chernozem, mm

Depth, cm	Suspended capillary moisture		Minimum moisture capacity		Capillary moisture breaking point		Minimum moisture	Wilting moisture
	Calculated	In field, June 1, 1951	Experimental	In field, June 20, 1851	Experimental	In field, July 7, 1951	September 1, 1951	
0—5	34	31	28	32	42	32[a]	37	17
5—10	24	20	19	17			19	
10—20	44	41	38	37	28	27	41	17
20—30	44	43	38	38	29	27	36	17
30—40	43	41	37	34	29	29	24	17
40—50	42	41	37	36	31	31	25	16
50—60	41	39	35	34	30	31	23	17
60—70	37	37	33	31	29	27	23	17
70—80	37	35	33	30	28	27	21	15
80—90	37	36	33	33	29	26	22	16
90—100	36	35	33	31	26	26	21	15
100—110	36	35	32	31	24	26	20	14
110—120	37	37	31	31	22	28	20	12
120—130	35	35	31	30	22	27	21	13
130—140	35	37	31	31	22	27	22	13
140—150	35	37	30	32	21	28	24	13
150—160	36	37	32	33	22	30[b]	24	13
160—170	37	39	31	34	22	31	25	13
170—180	37	38	31	34	22	32	24	12
180—190	36	35	31	33	20	32	26	11
190—200	35	32	31	33	22	31	21	11
200—210	35	30	32	34	23	32	22	11
0—200	778	761	675	675	520	575	519	300

[a] Figures within the bracket signify the capillary breaking point;

[b] Figures within the bracket signify the MMC.

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NEW CONTRIBUTIONS TO THE STUDY AND CONTROL OF WIND EROSION OF SOILS:

I. MECHANISM AND DYNAMICS OF WIND EROSION

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Considerable wind erosion of soils has been observed in recent years in various regions of our country, especially in the steppe zones, in view of the widespread plowing of new and abandoned lands without precautionary measures. Seedlings have been damaged on hundreds of thousands of hectares, and drifts have accumulated on non-eroded fields, pastures, roads, buildings, etc. (12, 14). In Pavlodar Oblast' alone, in three years (1955-1957) wind erosion enveloped about 40,000 hectares of various crop seedlings. Considerable areas of seedlings suffered from wind erosion in southern Ukraine, in steppe areas of Crimea, in a number of Oblasts of northern Caucasus, in Orenburg and Omsk Oblasts, in Bashkir, the Altay, Khakass, eastern Georgia, and in other places.

Wind erosion is observed almost every year in some regions. Even in the favorable year 1958, soil blowing and seedling injury occurred in Orenburg, Aktyubinsk, Kustanay, and other Oblasts. For example, in Pavlodar Oblast' of Kazakh SSR, wind erosion enveloped about 100,000 hectares of spring seedlings exclusively on spring plowing and even on virgin lands cultivated in 1958.

Besides the loss of seedlings, wind erosion leads to considerable soil damage. As a result of blowing, varying amounts of fine soil and humus are lost, lowering fertility. Plowed areas are changed into hummocky sand fields covered with weeds (13). Wind erosion is very strongly developed on coarse sandy and sandy loam soils which have been cultivated by methods worked out for fine-textured soils and for other environmental conditions. In areas of strong soil blowing, a unique grouping of soils — "aerolian complex" — develops, which is extremely variable in its characteristics and qualities for plant growth and development. Because of wind erosion, considerable areas are excluded from arable lands, and remain unsuited for plowing.

In the decisions of the XXI Congress of the Communist Party, special attention was given to bringing new land under cultivation, increasing soil fertility, and also to rational land use as the primary medium of agricultural production. In several regions of commercial grain production (Kazakhstan, Siberia, Ural, Volga, Ukraine, northern Caucasus), very great significance is attached to special measures directed primarily toward soil conservation, protection from wind erosion, and restoration of the fertility of eroded soils.

Science and practice have achieved well-known successes in the study of water erosion and in developing methods for its control. This cannot be said about wind erosion, which has comparatively recently received the attention of scientific and practical agriculturists, especiall considering the widespread utilization of land in regions of insufficient and undependable moisture. In view of the importance of the problem, I attempted a short review of the status of wind erosion studies, and the results achieved abroad.

The literature on wind erosion of soils and its control was extremely limited 15 to 20 years ago in our country (11) as well as abroad (30). Interesting and important results from a theoretical and practical viewpoint have been obtained in the relatively short period since then. Most of this work has appeared in journals published in the United States and Canada, which indicates the importance of the problem in these countries. Actually, close analysis of the published literature shows that the United States is presently becoming a country of extensive and intensive development of erosion and soil deterioration.

In the United States, wind erosion of soils is an especially serious threat to the agriculture of the Great Plains east of the Rocky Mountains. All of this territory, including the states of Wyoming, Colorado, New Mexico, Texas, North and South Dakota, Montana, Nebraska, Kansas, and Oklahoma, is characterized by strong, drying winds. The chernozem and hestnut soils utilized for agriculture have high ertility, and with sufficient, evenly distributed recipitation, they are capable of producing quite atisfactory yields.

In the initial agricultural development of the reat Plains, no attention was given to controling wind erosion, although its local developnent had been noticed by the end of the last entury (30, 34). But soon in this century, ith increasing numbers of cattle and general lowing, wind erosion increased and was obsered nearly every year. The droughts of the late wenties and early thirties were accompanied by ery widespread and intensive wind erosion, emracing the territories of several states. The o-called "Dust Bowl" was formed, which inluded states of the central and southern Great lains — North and South Dakota, eastern Colrado, western Kansas and Oklahoma, northestern Texas, northeastern New Mexico, and arts of Nebraska (20, 21, 34, 35, 36).

The most extensive and intensive wind eroion of soils occurred from 1933 to 1935. As result, seedlings of various crops were damged on almost one-third of the cultivated area f the United States, and fields in the Great lains lost one-hundred million tons of the most ertile parts of the soil (30, 34). Beginning in 930, following repeated wind erosion, 160,000 armers abandoned the Great Plains (34), and ook to the roads of America in search of food nd shelter, as was described by the American uthor Steinbeck in his book "Grapes of Wrath." he Dust Bowl produced in the Great Plains tarting in 1934 is unprecedented in its intensity nd size, as is maintained by the prominent merican specialist on erosion, Bennett (20). t the present time, wind erosion has affected bout 100 million acres of land in the United tates, of which 10 million acres remain praccally useless for agriculture (34, 36).

A similar situation prevails in Canada, where ind erosion is extensive, especially in the cenral agricultural regions — southwestern Manioba, and southern parts of Saskatchewan and lberta (28-31, 33).

The control of wind erosion is a matter of ational importance for the United States and anada, as specialists of these countries have ointed out.

Special government agencies were established or investigating the principles of the developnent and spread of wind erosion, and the damage caused to agriculture. The governments of ne United States and Canada expended considerble funds in establishing and equipping experiental laboratories. Wind erosion investigaons were organized at Colby (Kansas), Amarilo (Texas), Melit (Manitoba), Swift Current Saskatchewan), and elsewhere. T Canadian xperiment stations produced much valuable and interesting data on wind erosion and its control.

In several states of the USA (Kansas, Oklahoma, South Dakota, Nebraska, and others) and Canada (Alberta, Saskatchewan, and Manitoba), the agricultural experiment stations undertook investigations of wind erosion and development of soil conservation practices. In addition, field trials were conducted and soil conservation practices were introduced on individual farms under various soil and climatic conditions. The results of these investigations and trials were regularly published in the specialized literature.

Investigations on protecting soils from wind erosion were carried out along the following principal lines:

1. Studies on the physical nature, factors and dynamics of wind erosion in soils.

2. Studies of the influence of surface characteristics, physical and physical-chemical soil properties on the resistance and susceptibility of soils to blowing.

3. Studies of the influence of wind erosion on the physical, physical-chemical, and other soil properties.

4. Developing and studying different methods for protecting soils from wind erosion.

In this article, several questions relating to the first of these lines will be considered briefly.

The investigation of interrelations between wind and soil, and also the character of the soil surface, have great importance for developing rational methods to protect soils from wind erosion. However, because of the multitude of factors affecting wind erosion, field investigations on this problem are very difficult without laboratory experiments and construction of models. This fact naturally led to the construction and use of wind tunnels.

A special laboratory wind tunnel was constructed and used by Bagnold (18) in 1935-1936 for studying sand movement and dune formation.[1] Shortly afterward different types of laboratory wind tunnels were made in Canada for studying wind erosion on agricultural lands. In the forties, mobile wind tunnels were also established and mounted on automobiles with special arrangements for sampling the blown soil material. At present these tunnels have wide application in experimental work. They allow one to reproduce and study wind erosion processes at any time under different conditions and on different soils (22, 24, 38, 39). Only through the use of wind tunnels was it possible to solve a number of important, complex questions relating to the nature of wind erosion and having great importance for developing conservation practices.

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[1] Work on the establishment of a wind tunnel for studies on the wind-sand stream were carried out for several years starting in 1938 in the sand erosion laboratory of the Geology Institute of the Turkmen Academy of Sciences, headed by A.I. Znamenskiy (6-8). On the basis of the accumulated experience, an original wind tunnel was constructed in this laboratory in 1946, and is now used in studies of wind erosion of sands.

Wind erosion of soils is a complex phenomenon. The mechanical movement of soil particles under water and wind erosion have some similarities. These depend on the turbulent character of moving water and air streams, which is especially strong near the earth in the presence of surface irregularities. With both wind and water erosion of soils, three basic stages of soil particle movement are observed: 1) dislodging, 2) transportation, and 3) deposition.

Still the movement of soil particles in water and air streams show fundamental differences, depending on their kinematics. While in the water medium, soil particle movement is characterized by rolling along the stream bottom in the suspended state, whereas in the air medium, with rare exceptions, skipping forms of particle movement predominate. Wind erosion of soils has other characteristics, depending on the interactions of numerous and variable, direct or indirect, factors and forces with the soil particles.

Through investigations of our own and foreign scientists (1, 2, 3, 5, 9, 10, 15, 16, 25, et al.) it has been established that the following factors and conditions play some part in the development of wind erosion:

1. Wind (speed, direction, frequency), air viscosity and density, depending on pressure, temperature, and humidity.

2. Character of the relief.

3. Character of the soil surface (roughness, plant cover of residues, other obstacles).

4. Size and shape of fields undergoing erosion, their orientation with respect to winds causing erosion, the nature of surrounding fields, etc.

5. Soil properties (particle-size, aggregation, structural composition, amount and type of organic matter, etc.), soil temperature and moisture.

Thus, in addition to the action of strong winds and the presence of dry, exposed soil, other factors of varying importance are necessary for the development of wind erosion, while sometimes one factor may neutralize the effect of another. Certain of the indicated factors are very important. For example, even a small decrease in wind speed shows a substantial decrease in erosion intensity, because the force of the wind varies with the square of its velocity. Those factors having little effect include, for example, variations in air density under natural conditions arising from changes in temperature, pressure, and humidity. Another such factor is air viscosity (10, 25). From this it is obvious that in a given case, the role and significance of each factor must be studied and evaluated relative to the actual conditions.

The nature of the wind at the soil surface is very important for the development of wind erosion. At the end of the last century, Sokolov (10), in his remarkable work "Dunes, their origin, development, and internal structure," spoke of the decrease in wind velocity at the soil surface, writing that "the wind velocity must decrease especially sharply close to the surface itself, since movemen of the air layer lying next to the earth is greatly restricted by the direct interference of protruding surfaces, soil roughness, etc., while the upper layers are restricted only by internal friction, arising from the viscosity of the air itself, which is known to be small."

Recent investigations in Canada and the USA have confirmed and refined the observations of Sokolov. Numerous measurements have established that wind velocity is sharply reduced in the layer next to the earth, and becomes zero in irregularities of relief. In addition, a tenacious layer of slowly moving air develops directly on the soil surface. Its thickness is less than 0.05 mm on smooth, level surfaces. Thus, in the beginning stages of soil blowing, the wind catches up and transports only those particles which project beyond this tenacious air layer (19, 25).

As the soil surface is approached, the character and distribution of wind velocities follow aerodynamic laws, and depend mainly on the roughness of the soil surface. If wind velocity is plotted against the logarithm of height, a straight line is obtained according to data obtained under both laboratory and open field conditions. This proved that wind velocity gradients generally follow Prandtl's law, which expresses the velocity of the air stream at various heights as a function of forces of friction and heights of surface irregularities.[2] In Figure 1,

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[2] Pradtl's law has the form: $V_z = 5.75 \sqrt{Y/p} \log z/K$, where V_z is the wind velocity at a given height z; Y is the surface friction expressed in dynes per unit area; p is the air density; and K is 1/30 of the height of surface irregularities. In moving sands, Bagnold's studies (15, 16, 17) showed that the velocity gradient undergoes considerable variation, and Prandtl's law is not used for them at the present time. Bagnold

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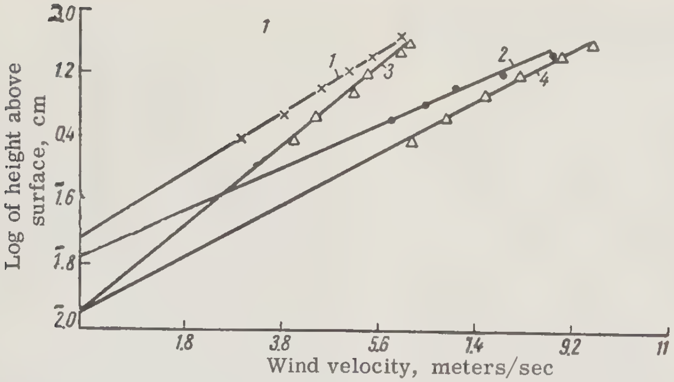

Fig. 1. - Wind velocity at different heights above various soil surfaces.

1 - clean fallow with a very cloddy surface; 2 - wheat stubble 17.5 cm high; 3 - clean fallow with a smooth surface; 4 - same as 3, but with a higher wind velocity (from Chepil).

ines 1, 2, and 3 intersect the ordinate at the alues 0.15, 0.10, and 0.02 cm. According o Prandtl's law, these correspond to surface rregularities 30 times as great, or 4.5, 3.0, nd 0.6 cm. These values correspond approximately to actual heights of surface irregularities, established from measurements in wind unnels as well as under natural conditions.

The wind causing soil erosion is always urbulent. In the work quoted above, Sokolov vrote that "apparently steady wind, upon inestigation, proves to be gusty, with separate, nore or less rapidly following gusts changing n intensity, and sometimes complete stillness." 'he gusty, turbulent nature of the wind, as okolov (10) mentioned, hinders the measurenent of its velocity. Thus, the available data n wind velocity at different heights is only pproximate and average. Measurements using n oscillating plate (23) supported the obserations of Sokolov. It was shown that turbuence arises from the effects on the air stream f soil surface roughness and convection caused y differences between soil and air temperaures. Turbulence of air streams brings about exchange of heat, moisture, and solids, and is characterized by the coefficient of turbulent exchange. According to approximate data, at a height of 20 cm from the surface the coefficient of turbulent exchange is 1/10 of that at 2 meters, and that at 2 cm is 1/10 of that at a height of 20 cm (4).

Wind erosion is promoted by turbulent air movement and to control it, measures tending to reduce turbulence are necessary. However, several practices for protecting soils from wind erosion are based upon the principle of creating obstacles to air movement, for example, furrowing, creating a rough, cloddy surface, leaving stubble, etc., which increase the turbulence of the air stream. Nevertheless, each type of hindrance significantly absorbs the force of the wind and weakens its effect on the soil. In addition, these obstacles retain a significant amount of the soil moved by the wind, thereby reducing the intensity of wind erosion and its damage. For example, it has been established that although furrowing increases turbulence, it decreases soil blowing markedly. In these cases the increase in turbulence is more than compensated for by a reduction in average velocity of surface winds, which cause soil blowing.

Sokolov (10) also established that sands, depending on their size, shape, and specific gravity, and their topography and wind velocity, move in the following ways: 1) by rolling (with impact) on the earth's surface itself; 2) by jumping (with skipping) at some height above the earth, touching the surface from time to time; 3) in suspension as dust clouds, sometimes rising to a considerable height above the earth.

Similar classifications of soil particle move-

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roved that the velocity of surface winds under sandy onditions is decreased by the effect of skipping paricles, and on this basis introduced several refinenents in Prandtl's law, giving it the following form:

$$V_Z = 5.75\sqrt{Y/p}\ (\log z/K') + Vt,$$

here K' is the height of sand ripples, and Vt is the ind velocity at height K'. Both of these values are onstant for all wind velocities exceeding the thresold. The most recent investigations have shown that cultivated soils, containing both erosive and nonrosive fractions, some decrease in wind velocity is lso observed from the effect of skipping particles. ut it is not as significant as in moving sands, which onsist almost exclusively of erosive particles (23, 24).

ment by wind were made in later work of a number of foreign investigators, without reference to Sokolov's work (16, 17, 19, 25, 27, 37, 38, and others).

Wind tunnel investigations of Americans and Canadians confirmed the essential truth of the mechanisms proposed by Sokolov for soil particle movement in wind and established their quantitative characteristics. They proved that the amount of soil transported by rolling, skipping, and in suspension varies widely and depends mainly on soil properties. However, in most situations, the largest amount of eroding soil material (50%-75% by weight) is transported by skipping. The most erosive soil particles, with diameters 0.1-0.5 mm, forming the initial stages of wind erosion, are transported in this manner. This strong tendency for these particles to blow is explained by the fact that they, being relatively large, protrude above the previously mentioned, tenacious surface layer of air, and are easily caught up into the air stream.

Depending on the force of the wind, skipping soil particles may begin to roll for short distances or be lifted up again into the turbulent air stream, and move forward. From time to time these particles strike the soil surface at angles of 6-12°, and again continue to move, or remain in place losing most of their energy in dislodging other coarse or fine soil particles.

The particles moved by rolling (dragging) are mostly coarser material, with a diameter of 0.5-1.0 mm and greater, and, depending on the nature of the soil, they constitute 5%-25% of the total soil mass transported by the wind. These particles are not set in motion by the direct effect of wind pressure, as are the skipping particles, but by impulses received from the skipping particles.

Lifting and transporting of fine soil particles (with diameters less than 0.1 mm) in suspension also appears as the result of soil particles skipping. The general opinion that more finely divided soils are more subject to blowing is true only to a certain extent, for silt particles measuring less than 0.05 mm in diameter, and especially less than 0.01 mm in diameter, resist blowing very strongly. These particles are easily brought into the air only if they are mixed with larger particles capable of being transported by skipping. The resistance of these particles to blowing is explained partly by strong adhesive forces between them, but mainly by the existence of the tenacious surface layer of air, which prevents particles of this diameter from protruding into the over-lying turbulent air stream (25). The quantity of soil transported in suspension varies within wide limits. Depending on the nature of the soil, it amounts to 3%-40% of the total soil mass transported by skipping and rolling.

The amount of soil particles transported by the wind, or the density of the soil-wind stream, is greatest at the soil surface and rapidly decreases with height. Also, the larger soil particles are transported closer to the surface than finer ones. For example, Figure 2 shows the relative amounts and average diameters of soil particles moved at different heights above the surface of clay loam and fine clay loam soils. The curves show that with a wind velosity of 6-10 meters/sec at a height of 30 cm, 60%-80% of the soil mass is transported at a height of 0-5 cm, more than 90% below 30 cm, and a very insignificant amount at heights above 95 cm. Thus, it may be said that wind erosion of soils is a surface process.

Znamenskiy (6, 7) obtained similar data, using a sand catcher, under the conditions of the Karakum dune sands.

Determination of the height to which skipping soil particles are carried is very important for the successful establishment of soil conservation measures, since the ability of stubble or furrows to hold blowing soil particles is largely determined by the height of the "jumps." Rolling or skipping soil particles are not taken far by the wind, and usually land close to the place of soil blowing. Transport of fine soil particles is facilitated by the turbulence of the air stream. Experiments have shown that silt particles of quartz can be held in the air by a wind velocity of less than 1-1.5 meters/sec. Therefore, silt lifted to hundreds and thousands of meters, is sometimes held for a long time in the air, transported great distances from its source, and comes down in the rain or settles when the wind velocity decreases or ceases.

The thredshold velocity, i. e. the minimum wind velocity necessary for dislodging and moving soil particles, is fundamentally important for the development of wind erosion. It is quite variable and depends on many factors — nature of the soil and its surface, frequency and intensity of wind erosion development, size of eroded area, etc.

A very important factor affecting threshold velocity is the soil particle diameter. Investigations have shown that particles from 0.05 to 0.15 mm in diameter have the lowest threshold velocities (Fig. 3). Dislodging and transporting these particles requires a wind velocity of about 3.5-4.0 meters/sec at 15 cm above the soil surface (25).

The threshold velocity for particles larger than 0.15 mm in diameter rises with increasing particle size, while that for particles smaller than 0.05 mm in diameter rises with decreasing particle size. Therefore, fine

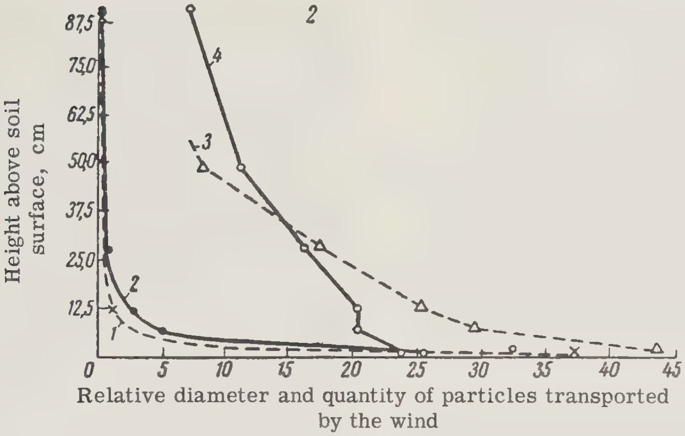

Fig. 2. - Approximate curves showing the relative amounts of soil particles carried by the wind at different heights.

1 - over fine clay loam; 2 - over clay loam; 3 - relative amount of blown particles 0.01 mm in diameter over clay; 4 - same over clay loam; (from Chepil).

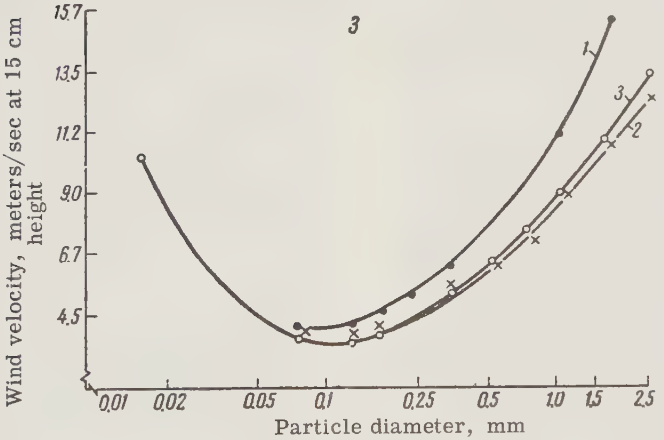

Fig. 3. - Minimum wind velocity necessary to initiate and maintain movement of soil particles.

1 - dune sand; 2 - sandy loam; 3 - fine clay loam (from Chepil).

ilt particles resist blowing very strongly, as vas mentioned previously. For example, quartz articles less than 0.05 mm in diameter were ot moved even with a wind velocity of 16 neters/sec at a height of 15 cm (25). But, if he soil is not uniform in particle-size compoition and an erosive fraction predominates, hese particles (less than 0.05 mm in diameter) nay be transported at lower threshold velocities. Similarly for moving particles, the dynamic" threshold velocity is lower than the tatic one.

Thus, the threshold wind velocity for soils vith heterogeneous particle-size composition is lower than that required for movement of coarse particles. The wind velocity required to initiate blowing of cultivated soils depends on many factors. The first soil blowing in each season requires higher wind velocity than later blowing. One of the reasons for this is the presence of a thin surface crust, which forms immediately after snow melts or rain and gradually disperses the soil. Another reason is the sorting effect of the wind, causing the accumulation of more or less uniformly sized soil particles, which have a much lower threshold velocity than the unsorted soil mass.

The threshold velocity of soils also depends on the previous history of the field. Soils previously eroded by wind (with formation of deposits) have a lower threshold velocity than those not previously eroded.

For a given soil, the threshold velocity varies within rather wide limits (5.8-6.7 meters/sec at a height of 30 cm) on fields with a smooth surface or on soils previously subjected to strong blowing (25). In order to protect soils from wind erosion, it is necessary to reduce the wind velocity close to the soil surface below the critical value mentioned. If this is not possible, other measures are necessary to increase the erosion resistance of the soil itself.

Numerous measurements have shown that when the soil consists only of erosive fractions, the intensity of blowing is well described by Bagnold's formula, proposed for the study of moving sands (23, 24). On cultivated soils, consisting of both erosive and non-erosive fractions, the intensity of blowing never remains constant, but depends on the duration of blowing, size and shape of the eroding field, velocity of the wind, degree of surface irregularity, and ratios and sizes of the erosive and non-erosive fractions. Experiments in wind tunnels have shown that the intensity of soil blowing is high at first, gradually decreases with time, and ceases entirely after the soil surface is stabilized by non-erosive fractions. Observations on narrow fallow strips have shown that the intensity of soil blowing decreases with continued blowing of the wind from one direction, and rises again when the wind changes to the opposite direction. Soil blowing on large fallow areas, once started, increases in intensity particularly on the downward side of the field. This is explained by an increase in the amount of erosive particles through the disintegration of non-erosive aggregates, large structural units, and surface crusts. On smaller eroding areas, there is less of this disintegration, less intensive blowing, and also less accumulation of eroding material, and less levelling of the soil surface (24).

The intensity of blowing under any conditions is zero at the leeward edge of a field and increases with distance toward the windward edge. In soils consisting only of erosive sand fractions, the distance necessary for development of maximum blowing intensity varies from 2.4 to 9 meters, depending on surface irregularity and particle size. In soils of average texture, this distance is much greater and may reach 450 meters (24, 25).

At the lower threshold velocities, soil blowing occurs on raised elements of relief and in exposed positions on calcareous and coarse soils, which are known to determine the minimum threshold velocity for a given erosive area.

Basically, wind acts upon soil in two ways. First, free particles are moved through direct pressure upon them. Second, particles are disintegrated and moved through being struck by skipping soil particles. Therefore, some investigators distinguish several forms of wind erosion, as follows (25):

Effluxion. This form of erosion is often characteristic of clay, calcareous, and sandy soils, in which blowing is initiated and continues through the direct effect of the wind. In these soils, movement of particles and aggregates 0.05-0.5 mm in diameter predominates. They move almost entirely by skipping, although an insignificant amount of larger particles may move by rolling, and smaller ones in suspension.

Extrusion. This form is observed on soils consisting primarily of coarse particles, which are also transported directly by the wind, but mainly by rolling. However, if the leeward side of this soil adjoins a strongly eroding field, blowing may be initiated by bombardment with fine particles originating in the neighboring field. Movement of the coarse particles, once started, usually continues even without bombardment.

Detrusion. This is a very strong form of erosion observed on freshly cultivated fields with irregular meso- and microrelief. It occurs on elevated and exposed places. Coarse soil particles are dislodged from protruding surfaces by high wind velocities, and collect in depressions on the leeward side of elevations.

Efflation. This includes the blowing of fine soil particles able to be transported in suspension. It is possible only in the presence of coarser, skipping soil particles. Efflation is the most serious form of erosion, in which the most valuable silt and clay particles are gradually lost.

Abrasion. This consists of the disintegration of soil aggregates through collisions with skipping particles. It is especially serious for freely occurring aggregates and in the presence of surface crusts.

All of these forms of soil erosion may develop independently, and often simultaneously in varying degrees. However, none of them are found without the participation of effluxion, in which movement of soil particles by skipping predominates.

Conclusions

1. The immense agricultural losses caused by wind erosion in the United States and Canada

stimulated the establishment of a number of experiment stations and various special wind tunnels and installations for the study of wind erosion processes in soils.

2. Through the use of wind tunnels and aerodynamic theories, definite progress was made in a comparatively short time in these countries in the explanation of the nature of wind erosion. Ideas were broadened about factors and dynamics of wind erosion development, the character of the soil-wind flow, and the forms of manifestation of wind erosion. Valuable data were obtained on the quantitative characteristics of wind transportation of soil masses by various methods of movement, etc.

3. The use of wind tunnels, and also laboratory and field experiments gave rise to new data on the physical-chemical properties of soils which favor or resist the development of wind erosion. They explained the effects of soil surface characteristics, vegetation and its residues, and methods of soil cultivation on the development of wind erosion. In the final analysis, all this made possible a more fundamental approach to the development of practical methods for protecting soils from wind erosion, which brings great harm to the agriculture of arid regions.

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SOME PARTICULARS ON SOIL FORMATION IN THE TUVA STEPPE DEPRESSIONS

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The soils of Tuva autonomous republic have not been studied to any extent to the present time. This includes the steppe soils which are the basic landscape of cultivated land.

Tuva soils were first described by Kirillov (8, 9), who completed several trips in the region from 1932 to 1934. In 1947, Petrov (18) and his coworkers explored the soils of central and western Tuva. On the basis of his material, a short soil description was prepared, with an outline map of the region. From 1952 to 1954, the soils group of the Tuva comprehensive expedition, sponsored by the USSR Academy of Sciences, studied the entire Oblast'. As a result, Nosin published articles (16, 17) broadening and refining the listing and location of soils in the Oblast'. The later reports of the Tuva comprehensive expedition (Vol. 3) contain material on the relief (13), climate (6), and vegetation (7).

The material obtained while working with the soils group permits me to express some opinions about soil formation on the steppes of Tuva autonomous Oblast'.

The geographic location of the Oblast' in the center of the Asian continent, at the junctions of two vastly different climatic regions, gives rise to an unusual combination of the eastern Siberian forest landscape with the Mongolian steppes in a relatively small area (170,000 sq km). One of the basic factors affecting the landscape and soils of Tuva is the relief. Its essential characteristic is the distribution of high mountain ranges that coincide with the borders of the Oblast' and constitute a high barrier, isolating the inter-mountain hollows and depressions from atmospheric currents. Such unusual orographic barriers are given on the north by the western and eastern Sayan Ranges, and on the south by the Tsagan-Shibet, western and eastern Tannu-Ola, and Sangilen Ranges. In the center is located the broad central Tuva depression, around which are found several more or less isolated depressions separated by mountain ridges (Khemchik, Chaakhol', Shagonar, Ulukhgem). In the depression between the ridges of the western Sayan is found the Turan depression. South of the Tannu-Ola Range is found the Ubsa Nor depression. Each depression is an individual geomorphic region, including the following elements of relief: broad foothill detritus, alluvial fans of numerous tributary streams, large river valleys with flood plains and terraces, elevated dry plains, and areas of rolling ridges.

Tuva has a severe continental climate characterized by cold, wind-less winters with little snow. Summers are hot with frequent, strong winds. Rainfall on the steppe depressions is light (about 200 mm annually). However, each depression has its climatic peculiarities, stemming from physiographic conditions, mainly relief.

Vegetation is another variable on the dry steppes. Detritus slopes and alluvial fans, blending into the broad steppe expanses, are covered mostly with snakeweed-wheatgrass and elm-wormwood-grass mixtures. The height of the vegetation is under 20 cm, and the cover is about 40%. Dry matter production is 2 to 4-5 cntr/ha. River terraces are occupied with bog, half-bog, and solonchak vegetation. On the rolling ridges, fescue and sedge-fescue steppes are found. A varied meadow grass steppe dominates the elevated plains of the valleys. Along with these general vegetative features, each depression has its peculiarities. For example, the Khemchik depression is distinguished by more widespread xerophytic vegetation because of its drier climate and type of soil parent-material. In the Ubsa Nor depression, scattered desert and desert-steppe groupings are widely distributed.

In the Tuva depressions, soil forms from calcareous parent-material derived, according to Polynov's studies (19), under a severe, dry, continental climate. The deposits of parent material consist of alluvium, eluvium, or deluvium of varying textures, but mostly gravelly sand or coarse clay loam.

The steppe soils of Tuva fall mainly into two great soil groups: chernozems and chestnut soils. The chestnut soils occur most frequently. Light and dark chestnut soils, southern and common chernozems occur less frequently.

Most of the steppe soils are gravelly in nature, and this characteristic increases with depth. Their texture is sandy or coarse clay loam, and the profiles are often a two-layer type. Fine sand and coarse silt fractions predominate in texture. The upper part of the profile may consist of a clay loam deluvium, while the lower part consists of ground rock eluvium with gravel contents often up to 80%. Occurrence of gravel and two-layer profiles is characteristic of most central Asian soils (3, 4, 14, 18).

Another characteristic of Tuva soils, compared with those of Europe, is their well developed micro-aggregation without a macrostructure (Table 1). The dispersion coefficient calculated according to Kachinskiy, varies from 5%-10%, confirming the high aggregation of the fine fraction. The water holding properties of Tuva steppe soils (Fig. 1) are no less unusual. In total porosity, these soils are no different from similar European soils. They are characterized by high porosity in the upper horizons (55%-61%), with a gradual decrease to 42%-45% in the lower horizons.

Tuva steppe soils differ sharply from European in their low field moisture capacity, which does not exceed 30%-55% of saturation in the humus horizons. In analogous soils of European USSR, the field moisture capacity is 50%-70% of saturation. The low field moisture capacity indicates the prevalence of large noncapillary pores which cannot hold water. Only the very dense calcareous horizon, apparently characterized by predominantly capillary pores, holds significant amounts of moisture (field moisture capacity about 60%-80%). The low field moisture capacity, and maximum hygroscopicity varying from 4%-7%, results in a low supply of available moisture for plants (10%-18%) in the humus horizons.

The data indicates unfavorable soil moisture properties, since the supply of available moisture is almost completely exhausted during the dry period of the year. Actually, determinations of field moisture made in July, 1953, showed an available moisture content of only 0.5%-1.0%. Tuva steppe soils are characterized by very high aeration porosity, especially in chernozems (up to 42%). The high aeration porosity substantiates the prevalence of noncapillary porosity, and results in vigorous development of aerobic processes, even during periods of adequate moisture, and gives a unique course of humus formation.

Our determinations of root masses indicated that rather large amounts of organic residues accumulate annually from the decay of plant root systems (Table 2). Nevertheless, there is little humus in these soils. Our calculations showed that the total amount in the 100 cm layer was 240-300 metric tons/ha in chernozems, 190-200 metric tons/ha in dark chestnut, 120-150 metric tons/ha in chestnut, and 100-110 metric tons/ha in light chestnut soils.

According to Tyurin (23) and Kononova (11, 12), the corresponding soils of European USSR contain, respectively, 425-400, 350-300, 250-200, and 200-150 metric tons/ha.

The humus profile of Tuva steppe soils differs markedly from that of corresponding European soils. The total humus content in the upper horizons, according to Nosin's data (16) and our investigations ranges from 9.0%-4.5% in chernozems, 5.5%-3.0% in dark chestnut, 3.5%-1.5% in chestnut, and 2.0%-1.0% in light chestnut soils. Such large variations in humus content within great soil groups and subgroups are related to soil texture and bioclimatic characteristics of the depression.

The highest humus contents characterize the soils of northern Tuva depressions and headwaters of the Yenisey. The lowest humus contents characterize those of western Khemchik and southern Ubsa Nor depressions. This is caused by the increasingly continental and dry climate in proceeding from northeast to southwest, and also by a decrease in altitude in the same direction.

The humus profile of Tuva steppe soils is shallow. The principal amount is confined to the upper 50 cm layer. This distribution is not characteristic of the European soils. If we compare our data with that of Prasolov, Antipov-Karatayev (21), Nosin (15), Gradoboyev (5), and Kolyago (10) on soils of the Volga and Khakass regions, the unique humus profile of Tuva soils stands out even more (Fig. 2).

Data on the fractional composition of humus, obtained, by Tyurin's method (22), also emphasize the peculiarity of Tuva steppe soils compared with European (Table 3). In spite of the high Ca saturation, humus is very soluble in these soils. A considerable portion of it is extracted with 0.1 N NaOH solution, which is completely atypical for European steppe soils. The humic acid fraction firmly bound with the mineral soil is practically absent. Yet in European soils, according to Tyurin (23) and Bel'chikova (2), with the same total content, most of the humus is firmly bound with the mineral soil.

Table 1

Particle and micro-aggregate-size distribution of Tuva steppe soils in percent of dry soil

Soil	Depth, cm	Size fraction, mm									Kachinskiy's dispersion coefficient
		>1	1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01	>0.01	
Clay loam southern chernozem (D-56)	0—14	6	$\frac{10}{12}$[a]	$\frac{33}{50}$	$\frac{20}{27}$	$\frac{3}{2}$	$\frac{12}{2}$	$\frac{16}{1}$	31	69	·6.24
	15—25	5	$\frac{11}{14}$	$\frac{36}{51}$	$\frac{19}{22}$	$\frac{3}{4}$	$\frac{11}{3}$	$\frac{15}{1}$	29	71	6.66
	30—37	18	$\frac{14}{12}$	$\frac{41}{51}$	$\frac{11}{22}$	$\frac{1}{4}$	$\frac{8}{3}$	$\frac{7}{1}$	16	84	14.3
	50—60	6	$\frac{11}{9}$	$\frac{39}{50}$	$\frac{16}{22}$	$\frac{1}{4}$	$\frac{11}{4}$	$\frac{16}{5}$	28	72	31.2
	80—90	1	7	28	19	4	16	25	45	55	—
	100—110	1	$\frac{8}{7}$	$\frac{32}{50}$	$\frac{19}{27}$	$\frac{5}{10}$	$\frac{15}{3}$	$\frac{20}{2}$	40	60	10.0
	170—180	37	38	17	2	1	3	2	6	94	—
Sandy loam dark chestnut soil (Yu-138)	0—10	—	6	65	10	3	7	9	19	81	—
	13—23	—	9	68	9	1	5	8	14	86	—
	23—33	—	10	72	6	1	4	7	12	88	—
	45—55	—	10	73	6	1	4	6	11	89	—
	70—80	—	9	81	3	—	3	4	7	93	—
	115—125	—	13	79	2	—	3	3	6	94	—
Coarse clay loam chestnut soil (Yu-387)	0—15	4	4	47	23	4	12	10	26	74	
	15—20	12	4	25	32	14	13	12	39	61	
	30—40	9	2	9	57	12	12	8	32	68	
	60—80	40	4	10	62	9	11	4	24	76	
	90—100	88	3	17	58	6	11	5	22	78	
Coarse clay loam light chestnut soil (Yu-305)	0—9	6	14	53	13	2	11	7	20	80	
	9—17	7	15	61	5	1	8	10	19	81	
	17—27	68	47	32	6	3	5	7	15	85	
	45—55	76	63	27	2	2	4	2	8	92	

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[a] Numerator gives particle size, the denominator micro-aggregate size.

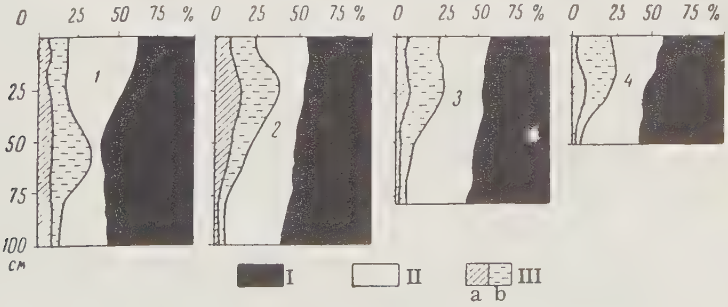

Fig. 1. - Field moisture capacity and aeration porosity in the steppe soils of Tuva autonomous Oblast'.

1 - clay loam southern chernozem, D-56; 2 - sandy loam dark chestnut soil, Yu-138; 3 - coarse clay loam chestnut soil, Yu-387; 4 - coarse clay loam light chestnut soil, Yu-305.

I - solid phase; II - aeration porosity; III - field moisture capacity; a) unavailable moisture; b) available moisture.

Table 2

Quantity of humus, roots, and above-ground vegetation in the soils of Tuva and European USSR in tons per hectare and percent of total content

Soil	Quantity of humus			Quantity of roots in 50 cm layer	Above-ground vegetation
	In the A horizon	In the upper			
		50 см	100 см		
Tuva autonomous Oblast'					
Clay loam southern chernozem	96.5[a]/43	213.0/94	225.0/100	19.2	5.3[c]
Clay loam dark chestnut soil	67.2/31	193.0/90	213.0/100	11.7	3.3[c]
Coarse clay loam chestnut soil	39.1/33	96.6/83	115.6/100	6.1	2.3[c]
Coarse clay loam light chestnut soil	20.3/18	93.6/86	109.6/100	4.7	2.1[c]
European USSR					
Common chernozem[b]	137/32	213/50	426/100	20.0	5.0
Dark chestnut soil[b]	129/	165/55	300/100	15.0	3.9

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[a] The numerator gives metric tons per hectare, the denominator percent of total content.

[b] Data of M. M. Kononova (9).

[c] The weight of above-ground vegetation includes the crowns of dense bunch grasses.

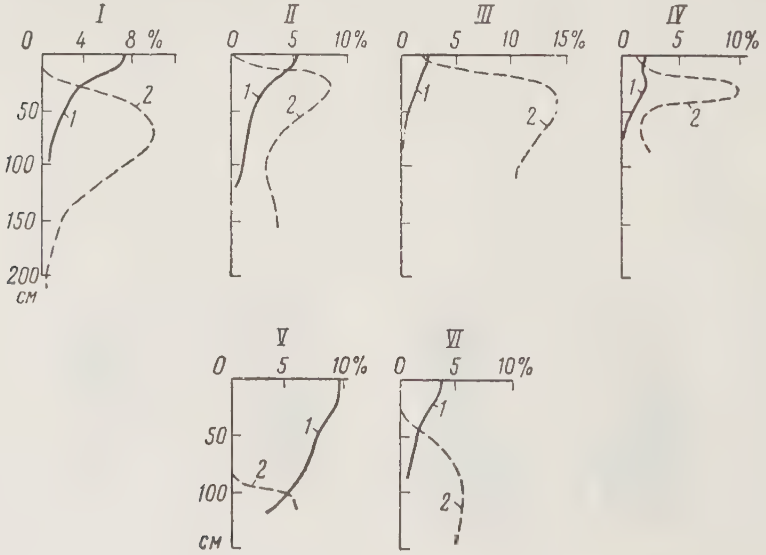

Fig. 2. - Humus and carbonate profiles of steppe soils of the Tuva autonomous Oblast' and European USSR.

I - IV - soils of Tuva autonomous Oblast': I - clay loam southern chernozem; II - clay loam dark chestnut; III - clay loam chestnut; IV - coarse clay loam light chestnut soil; V - VI - soils of European USSR; V - clay loam common chernozem; Strelets steppe, Kursk Oblast' (1); VI - clay loam chestnut soil. Volga region (16).

1 - humus; 2 - CO_2.

Table 3

Fractionation of humus from the Tuva steppe soils in percent of total humus

Fraction	Chernozem			Dark chestnut		Chestnut		Light chestnut	
	Depth, cm								
	0–14	15–25	30–36	0–10	15–21	0–15	15–35	0–9	9–17
Soluble in alcohol-benzene	4.2	3.5	3.2	3.8	3.3	3.8	3.6	3.5	3.3
Humus:									
Fraction I	43.1	33.4	28.5	38.9	35.3	30.4	21.5	21.6	18.6
Humic acid in I	21.9	13.8	not det.	18.8	not det.	13.1	not determined		
Fraction II	20.8	29.2	34.1	23.2	25.3	34.5	41.0	35.6	40.1
Humic acid in II	13.5	15.1	not det.	14.2	not det.	21.6	not determined		
Fraction III	0.4	0.5	1.0	0.7	0.6	0.3	0.3	0.2	0.6
Humic acid in III	0	0	0	0	0	0	0	0	0
Total humic acid	35.4	23.9	—	33.0	—	34.7	—	—	—
Total fulvic acid	28.9	34.2	—	29.8	—	30.6	—	—	—
Ratio: $\frac{\text{humic acid}}{\text{fulvic acid}}$	1.2	0.85	—	1.1	—	1.1	—	—	—
Unhydrolyzable residue	29.6	32.0	30.5	31.3	34.2	30.0	33.7	37.4	35.6
Total	98.1	98.6	97.3	97.9	98.7	99.0	100.1	98.3	98.2
Total quantity of humus in % of dry soil	6.89	3.60	2.00	5.6	3.94	2.17	1.93	1.92	1.43

The humus composition is explained, first, y the absence of sufficient colloid content (4.4%), nd the low amount of clay particle on whose surace the humus is mainly fixed.[1] Secondly, the omposition is explained by the particular hydroiermic conditions, under which organic resiues decompose very intensively during a short eriod (end of July to the middle of August) nder predominantly aerobic conditions.

Some data on the chemical composition of 'uva steppe soils are presented in Table 4. 'he low colloid content in these soils gives a ow exchange capacity. Even in chernozems : is less than 25 meq, and it falls to 13-8 meq ı light chestnut soils. The ratio of Ca to Mg s very narrow. The amount of exchangeable 'a is small, not exceeding 5% even in the lower orizons.

A morphological characteristic of Tuva teppe soils is a massively impregnated lime layer with 21%-32% $CaCO_3$. The origin of this unique calcareous horizon is not clear. Characteristically, its upper edge coincides with the penetration depth of the main root mass. Its genesis is probably connected with the circulation of $Ca(HCO_3)_2$ solution in the profile and the rise of capillary water during the dry season. The $Ca(HCO_3)_2$ comes in the rising stream at the root zone, where its concentration increases as moisture is removed by plants. This, together with increased temperature, leads to the transformation of bicarbonate into insoluble forms, and the accumulation of large quantities of mealy lime.

European chernozems and chestnut soils are characterized by quite a different carbonate profile, where new lime forms in small amounts as white flecks or nodules.

In the profile of Tuva steppe soils, large amounts of soluble salts and gypsum do not accumulate, such as are observed in the soils of European USSR.

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[1] The amount of colloid was determined in the 0-14 n layer of a Tuva chernozem (D-56).

Table 4

Chemical characteristics of Tuva steppe soils, percent of dry soil

Soil	Depth, cm	Hygroscopic moisture	Humus	CO_2	SO_4	pH in water	Exchangeable cations meq/100g soil			Exchange capacity meq.	Dry residue from water extract, %
			In %				Ca^{++}	Mg^{++}	Na^+		
Clay loam southern chernozem (D-56)	0—14	2.21	6.89	0.09	—	7.93	22.99	5.52	0.2	29.76	0.079
	15—25	1.96	3.60	0.53	—	7.80	17.85	5.11	0.3	20.88	—
	30—37	1.21	2.00	4.41	—	8.41	8.35	2.11	0.3	—	0.067
	50—60	1.06	1.50	10.00	—	8.69	—	—	—	11.18	0.072
	80—90	1.23	0.85	7.81	0.09	8.62	—	—	—	—	—
	110—120	1.35	0.55	4.40	0.81	8.31	—	—	—	12.22	0.620
	170—180	0.45	—	0.88	—	8.73	—	—	—	—	0.048
Sandy loam dark chestnut soil (Yu-138)	0—10	1.45	3.23	0.04	—	7.6	16.36	2.05	0.6	not det.	0.059
	13—23	0.30	1.67	0.04	—	7.8	12.72	2.52	0.6	"	0.070
	23—33	0.34	1.21	0.47	—	8.0	8.3	3.0	Trace	"	—
	45—55	0.33	1.05	2.53	—	8.19	11.5	4.22	"	"	0.068
	70—80	0.45	1.98	1.74	—	8.31	—	—	—	—	—
	115—125	0.58	0.14	0.72	—	8.48	—	—	—	—	0.066
Coarse clay loam chestnut soil (Yu-387)	0—15	1.15	2.17	1.49	—	9.03	10.95	3.36	0.03	14.61	0.051
	15—25	0.96	1.93	11.57	—	8.72	9.57	3.36	0.03	13.23	—
	30—40	0.63	0.69	14.06	—	8.44	—	—	—	7.34	0.085
	70—80	0.54	0.24	12.02	0.24	8.37	—	—	—	5.78	0.398
	90—100	0.79	—	10.18	0.19	8.60	—	—	—	—	—
Coarse clay loam light chestnut soil (Yu-305)	0—9	1.49	1.92	1.57	—	8.76	8.15	4.65	0.2	13.10	0.096
	9—17	1.20	1.43	2.46	—	8.70	7.83	0.83	0.2	8.86	—
	17—27	1.00	2.07	10.63	—	8.19	—	—	—	10.41	0.125
	30—40	0.60	1.21	5.16	0.09	8.45	—	—	—	—	—
	45—55	0.57	—	1.15	0.03	8.55	—	—	—	—	0.054
	70—80	0.60	—	2.08	0.03	8.45	—	—	—	—	0.07

Conclusions

1. The majority of Tuva steppe soils are characterized by coarse-texture and a gravelly profile. A two-layered textural profile is often noted.

2. The water relations of Tuva steppe soils are unique. They are characterized by low field moisture capacity, indicating the prevalence of coarse non-capillary pores and causing low available moisture supply for plants. High aeration porosity assures vigorous aerobic processes even during periods of sufficient moisture.

3. The steppe soils of Tuva autonomous Oblast' are distinguished by quite low humus supply and a shallow humus profile compared with similar soils of European USSR. Peculiarities of humus in these soils are high solubility and the absence of a fraction firmly bound to the mineral soil.

4. A morphological characteristic of Tuva steppe soils is the presence of a massively impregnated lime layer. The genesis of this unique horizon is connected with circulation of $Ca(HCO_3)_2$ solutions in the profile and the rise of capillary-suspended water in the dry season.

5. In the profile of Tuva steppe soils, large amounts of soluble salts and gypsum do not accumulate, such as are noted in the soils of European USSR.

6. The particulars of steppe soil formation in the Tuva depressions, just enumerated, depend on the parent material and hydrothermic conditions in the Oblast'. Soil formation occurs on material with insufficient clay and colloids. The decomposition of plant residues proceeds very intensively in a short time.

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FIELD NOTES ON THE SOILS OF IRAN[1]

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A group of Soviet delegates to the Teheran Symposium of the UNESCO on the Problem of Salinization of Soils and Water in Arid Zones had the opportunity to familiarize themselves with some regions of Iran during a round-trip journey by rail from Dzhulfa to Teheran. The group also participated in two excursions organized by the Symposium to experimental drainage sections at Gezelkhezar and Garmsar and a three-day trip by air and automobile from Teheran to Shiraz and back. During these trips, 12 soil Profiles were exposed, several outcroppings were inspected, and observations were made of the character of the natural and agricultural landscapes. Moreover, the delegates became acquainted with splendid monuments of the past of this country.

The literature on the natural conditions of Iran, particularly on its soils, is quite poor. Iranian scientists have only recently started to study the soils of their country. Comparatively small areas have been subjected to study for irrigation purposes or for carrying out reclamation measures. Thus, Iran does not have a soil map of its own. In addition, there is no map of the vegetation even though the flora has been studied for a long time and five issues of the Flora of Iran in the French language have appeared to date. Apparently, the sole source for becoming acquainted with the general character of the soils of Iran is the soil map compiled by Kovda and Lebedev (1), the varient of the latter with supplements and an outline compiled by Petrov (2, 3).

Iran is a mountainous country. Lowlands with altitudes up to 200 meters exist only in the Shatt al Arab Delta (formed by the confluence of the Tigris and the Euphrates) and on the shores of the Caspian Sea, the Persian Gulf, and the Gulf of Oman. Lowlands with altitudes of 200-500 meters are also few. Mountain ranges, plateaus, and mountain valleys with altitudes above 500-1000 meters predominate.

The northern part of Iran, with the exception of the Caspian Coast, is occupied by the Elbrus mountain system with the sharp peak of Demavend (5,604 meters), which is a dead volcano covered with perpetual snow. To the east, the Elbrus system turns into the Turkmen-Khorosan Mountains and in the west into the Armenian Highlands. These highlands are composed of rock of different ages (from the Devonian to the Eocene) and petrographic composition (clay shales, sandstones, marls, limestones, granite intrusions, tuffs, basalts, porphyries, etc.). As a whole, these mountain chains form the "northern folded zone" which constitutes a very important bioclimatic boundary.

The southwest and southeast parts of Iran consist of a system of mountain ranges (up to 4,300 meters) and mountain valleys. The Zagros mountain chain and the Southern Iranian Mountains which stretch along the Persian Gulf and the Gulf of Oman belong to the first part. The Kermanshah and the Shiraz valleys are among the large mountain valleys. Thick layers of sedimentary rock ranging from the Paleozoic to the Tertiary prevail in the Zagros Mountains while rock from the Upper Cretaceous to the Pliocene prevail in the Southern Iranian Mountains with saline domes in some places. The mountain valleys are composed of layers of stone and pebble deposits. This mountain system forms the southern folded arc.

The central part of Iran is a large, comparatively low area between the mountains; it is quite flat and low (500-1000 meters) in the center and in the east and is elevated (up to 2,000 meters) and more highly dissected on the periphery. This depressed area is filled with deposits of alluvial and proluvial origin. Mountain ridges and individual buttes rise in the center; they are composed of Paleozoic and Mesocenozoic sedimentary rock with intrusions of granite and other rock, also effusive rocks; saline domes have been noted in some places. As a whole, this area between the mountains is known as the Iranian Plateau while its central portion is known by the Dasht-i-Kavir and Dasht-i-Lut Deserts.

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[1] Given before the United Meeting of the Second and Sixth Commissions of the All-Union Society of Soil Scientists.

The hydrographic network is weakly developed in Iran and there are very few rivers. The largest of these, the Karun River, flows into the Shatt al Arab. The majority of rivers in northern Iran (the Aras, Atrek, Gorgan, Sefid, and others) are associated with the Caspian Basin. The rivers on the southern slopes of the Elbrus system are small and almost all of their water is used for irrigation. The large river of the Iranian Plateau is the Zayenderud River whose waters are used to irrigate the Isfahan Oasis. The central and eastern parts of Iran are almost devoid of water if we do not count the salt lakes. On the other hand, the underground flow is quite abundant, a circumstance which has brought about the extensive development of irrigation by underground streams (Kyariz irrigation) in Iran.

The climate of Iran is formed essentially under the influence of dry Mediterranean air. Its dampest regions (up to 1,500 mm of precipitation) are associated with the Caspian Sea Coast; the driest region (less than 50 mm) is found in the Sistan Basin, which bounds on Afghanistan. The high mountain chains of the Elbrus system prevent the cold air masses from the north from penetrating into the south and restrict the spread of the moderating influence of the Caspian Sea on the Trans-Elbrus portion of the country. The effect of the Indian Ocean monsoons is very small and does not extend far into the country. Therefore, the climate of most of Iran is dry and very hot. The mean annual air temperature varies from 11°C (in the north) to 24°C (in the south) while the mean January temperatures vary from - 2°C to + 1°C (in the north) to 14°C-19°C (in the south). Atmospheric precipitation amounts to 100 mm (and less) to 500 mm. Over 80%-90% of the precipitation is associated with the cold half of the year, chiefly the winter. This is particularly characteristic of the southern part of Iran where the Mediterranean branch of the polar front penetrates to the Persian Gulf, providing the origin for the subtropical winter rains. For this reason, more precipitation falls in southern Iran than in the north, particularly in the center, at the same absolute altitude. For example, precipitation amounts to 245 mm at Teheran (north), 123 mm at Isfahan (center), and 289 mm at Shiraz (south).

The Soviet delegation was given the opportunity of familiarizing themselves with the natural conditions of the foothill valleys of the southern slopes of the Elbrus system, the northern edge of the Dasht-i-Kavir Desert, the central Iranian Plateau, and the Shiraz Mountain Valley. According to the previously mentioned soil maps, different sierozems (leached, dark, typical, and light), meadow-solonchak, and solonchak soils are spread throughout this territory. The soil map on a scale of 1:4,000,000 compiled by Rozov (4) with the assistance of Ye.V. Lobova indicates also that there are cinnamon-brown forest and gray-brown soils. According to Petrov (3), the vegetation is represented by: small shrubs and ephemeral vegetation in foothill and mountain valleys and phryganoid (mountain xerophytes) on the mountain slopes.

A sharp predominance of stone and pebble deposits in the foothill valleys and in the mountains was typical of the entire territory through which our itinerary led. Fine-textured parent-materials were encountered very rarely; in the overwhelming majority of cases they were thin and associated with the lower portions of proluvial talus and with depressed areas on them. Loessial materials were not encountered. Beyond Kazvin, however, (from Teheran) fine-textured clay loams are apparently one of the chief parent materials.

We inspected another characteristic peculiarity of the territory which consisted of the fairly widespread existence of the so-called outcrop zones where underground water comes from mountainous elevations. Depending on the size of the underground stream and the character of the lithology of the soil, the degree of development in these zones varies greatly — from the scarcely noticeable to the very strongly developed with enormous supplies of underground water, frequently of good quality and lying close to the surface. These outcrop zones play a large role in the national economy since many irrigated oases with good, fertile, and fine-textured soils and with favorable conditions for obtaining irrigation water are associated with them. However, not all the land in the outcrop zones is under agriculture because of the salinization and formation of solonetz soils.

During the first excursion to the experimental area at Geselkhezar (60 km west of Teheran, in the vicinity of the city of Karaj), we were shown the construction project of an experimental drainage system in a non-cultivated depressed part of an outcrop zone of fresh underground water of alkaline character lying at a depth averaging 140-170 cm. The soils were not homogeneous, stratified, and consisted of a predominance of fine clay loams and clays. The vegetation was of meadow-solonchak type which included: Aeluropus littoralis, liquorice, small rushes, different saltworts (Petrosimonia, Suaeda sp. Salsola sp.). wormwood, and camphor-bearing plants in some places. A detailed topographical map of the area had been compiled, the soils were studied carefully through several Profiles, but a soil map had not been made; one was planned on a scale of 1:50,000 to be followed by another on a scale of 1:10,000. Construction had been started on an open drainage system with a depth of 1.8 meters with ditches 180 meters apart and with collectors 2.5 meters deep. According to the determinations made by the Soviet delegation, the soils of the area were represented by the complex: 1) meadow soils of different degrees of salinization and solonetz characteristics; 2) sodium-carbonate and sodium-sulfate meadow solonetz soils; 3) meadow solonetz and solonchak soils. This area had much in common with respect to soil conditions corresponding to areas in the Chui Depression of the Kirgiz SSR. The opinion was expressed that when the area was put under cultivation it would be necessary to pay attention to controlling solonetz characteristics by applying gypsum, a measure that had not been planned. Care would have to be taken not to cause excessive drying out by drainage and to prevent the reclamation from deteriorating, especially if the land were maintained under cultivation.

On the second visit to this area, two Profiles were taken (cloddy meadow solonetz and solonetz-solonchak) and adjacent land that was under cultivation was inspected. The condition of the crops was not satisfactory as there had been large losses in spots with solonetz soil. Farther up the slope, however, where the soils were not saline or solonetz and where there were apparently meadow and sierozem-meadow soils with weak solonetz characteristics, the crops were better. Still higher on the slopes this complex was replaced by sierozems on a stone and pebble talus with a thin fine earth cover, partially under dry land wheat or under winter irrigation. Profile No. 15 was taken at the contact with this talus from an area under irrigated wheat. Its Profile contained a thick (up to 60 cm) cultivated, humus-containing (with 1.4%-2.9% humus) horizon of a bluish-gray color. Below this was a horizon with a cinnamon-brown tint with nut-like structure, calcareous white-flecks and clearly marked inclusions of clay formation (Table 1). The lower part of the Profile (from a depth of 120 cm) is marled with pebbles and stones and has a bluish color which provides evidence of past bogginess from water outcropping near the surface, but this is not observed at present. In the structural Profile this soil is close to cultivated meadow sierozem and, possibly, to meadow gray cinnamon-brown soils. We point out here that gray cinnamon-brown soils were noted by visual observation in the vicinity of Kazvin under the wormwood-beard grass steppes.

The second experimental area at Garmsar is located in the northern part of the Dasht-i-Kavir Desert and is also located in a water outcrop zone, but in contrast with the first, is subject to the influence of strongly mineralized (20-40 g/l) ground-waters which contain chlorides and sulfates. This is associated with the fact that the neighboring foothills are composed of saliferous Tertiary rocks. White deluvial streaks of salt on the mountain slopes are characteristic. The Khablinrud River which intersects these foothills leaves masses of salt on its banks even though its waters are used for irrigating the oasis on the stone and pebble slopes. The underground water for irrigation is distinguished by increased mineralization (up to 2.6 g/l). The experimental area is associated with the lowest and the most highly salinized parts of the water outcrop zone. The ground waters lie at a depth of 1.2-1.5 meters. The soils are lens-shaped stratified clays and clay loams with strong traces of gypsum and they are gleyed in the lower layers. The vegetation is of a solonchak type: Halocnemum strobilaceum, Kalidium caspicum, Salicornia, Suaeda, Aeluropus littoralis, and others. The soils are meadow and friable crust solonchak and meadow solonchak, with sulfate-chloride and chloride-sulfate salinized with a large gypsum content beginning at the surface. Drainage with a depth of 2-2.5 meters is planned for this area.

Less saline land with a deeper water table (2.0-3.0 meters) is located somewhat higher and is under cotton, alfalfa, and melons — with the help of drainage and irrigation. In the examined area, under cultivation for five years, the condition of the crops was still quite spotty with large losses, particularly in the fields under cotton. In this connection, the Soviet delegation expressed the desirability that more attention be devoted to working out rapid and effective methods for cultivating the more highly saline areas which predominate in this locality.

The solution of the problem of the zonal soil groups was made more difficult by the almost complete absence of fine-textured deposits, on the routes of the trips that were made, in which the character of soil formation is shown in the most clear-cut form.

Nevertheless, one can state with sufficient certainty that the soil Profiles (1, 2, 16) taken on proluvial stone and pebble slopes on the route from Teheran to the northern edge of the Dasht-i-Kavir show the outlines of the structure characteristic of sierozems. This is shown best of all in Profile No. 1, taken 10-12 km east of Teheran, which contains: 1) a plowed horizon of grayish color (1.2% humus) with clay vessel shards; 2) a sub-plowed horizon, lighter color (0.7% humus), compacted and somewhat blocky; 3) a stone (pebble) clay loam (from 45 cm) with faded calcium-carbonate flecks and with limestone crusts on the pebbles. Its texture is fine clay loam. The CO_2 content is high and a weakly illuvial nature is noticeable (Table 1). The features of an ordinary (typical) sierozem

Table 1

Several chemical and particle-size analysis of the fine earths from northern Iran, percent[a]

Profile No. and name of soil	Depth, cm	Humus	CO_2	Diameter of fractions, mm			
				Sand 1—0.05	Silt 0.05—−0.001	Clay <0.001	Physical clay <0.01
I — 1. Ordinary sierozem, silt medium clay loam	0—10	1.20	8.5	15.5	63.7	20.8	57.5
	20—30	0.74	9.0	22.7	59.6	17.7	52.7
	55—65	0.57	9.1	22.1	56.0	18.3	50.6
I — 16. Light sierozem sand to sandy loam, coarse texture	0—10	0.64	0.5	69.6	26.6	3.8	11.4
	10—25	0.41	1.2	68.0	26.2	5.8	15.8
	40—50		3.3	93.3	5.5	1.2	3.4
I — 2. Desert sierozem, sand to sandy loam, coarse texture	0—10	0.31	4.7	80.5	12.5	12.0	13.5
	15—25	0.20	6.2	76.8	14.0	9.2	17.1
	35—45		6.0	73.3	18.1	8.6	17.5
I — 15. Meadow sierozem, deeply cultivated, silty clay	5—15	3.35	2.2	11.2	66.7	22.1	66.3
	30—40	0.98	5.1	9.5	57.0	33.5	73.2
	50—60	0.81	7.7	13.5	56.4	30.1	68.3
	70—80	0.65	9.9	16.5	56.0	27.5	64.4
	100—110	0.65	12.2	18.8	58.1	23.1	59.6
	130—140	0.57	9.3	12.1	59.9	28.0	66.7

are apparent in this Profile.

Profile No. 2 (taken 60-70 km east of Teheran) is characteristic of soils under ephemeral-wormwood-saltwort vegetation. The top layer (to 10 cm) consists of a friable, stone sandy loam with a very thin porous crust on the surface; the color is brownish light-gray with a fairly large number of plant roots. It passes into a finer sandy loam with a cinnamon-brown tint, slightly compacted with faded calcium-carbonate traces. Below this (from 40 cm), stones and pebbles begin with a small admixture of sandy loam soil of the same cinnamon-brown tint and with carbonate crusts on the surface of the stones and pebbles. Gypsum appears in small quantities from 60-70 cm. All the humus is contained in the 0-10 cm layer in the amount of 0.3%. The maximum CO_2 is associated with the middle portion of the Profile. In the field this was classified with desert stone sandy loam sierozems.

Profile No. 16 (taken 15 km west of Teheran) has the characteristics of the soils of a stone, pebble wormwood-saltwort semidesert with a fairly well developed cover of ephemerals. The upper horizon was brownish light-gray with a large amount of tiny roots. It passes into a more highly compacted cinnamon-brown light-gray (lighter than the upper horizon) horizon, with a considerable amount of carbonate crusts on the surface of the stones and pebbles. Below 35 cm are stones, pebbles, and coarse sand with carbonate crusts. There is no gypsum. The small CO_2 content in the upper horizon, its sharp increase with depth, and the markedly more clear-cut clayeyness of the middle portion of the profile, as compared with Profile No. 2 (Table 1), are characteristic. The soil texture of the fine earths is sandy loam and sandy below 30 cm. The humus content in the 0-10 cm layer is 0.6% (Table 1). The characteristics of this soil are close to those of light sierozems. Its comparatively low carbonate content is apparently caused by the lithology of the parent materials.

We obtained an idea of the zonal soils of southern Iran in the course of our trip from Isfahan to Shiraz by automobile. The stone wormwood-saltwort desert began immediately beyond the ancient Isfahan irrigated oasis on the upper slopes of mountainous elevations, almost devoid of vegetation. The soils had very poorly defined Profiles and small quantities of fine earths and were of a brown or cinnamon-brown tint; new carbonate or gypsum formations were not noted. But even here, small areas of bare takyrs with scattered stones and individual clumps of anabasis are encountered in depressed places. Many of them are cultivated through conduit irrigation and are saline to some extent since salt traces were noted on the surface of the irrigated fields. As one leaves the mountains the stone desert is replaced by a pebble desert; a more dense vegetation and ephemerals appear.

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[a] Analysts: A. V. Kozlova (humus, by the Tyurin method); V. A. Molodtsov (CO_2, by the Golubev method); and particle-size analysis with the use of sodium hexametaphosphate).

These changes become more noticeable as one proceeds farther south. The number of ephemerals increases greatly; one frequently sees the high stalks of ferula; different small shrubs and thorn bushes appear; and the grass becomes more dense. The surface of the soils acquires cinnamon-brown and even red shades. The same colors are also characteristic of the weathered surfaces of the solid rock which composes the mountainous elevations.

The soils of these deserts are characterized by Profile No. 5 (taken 100-110 km from Isfahan) under ephemeral-wormwood vegetation with ferula and with small xerophyte bushes. The soil Profile consists of: 1) 0-2 to 3 cm straw-colored cinnamon-brown crust, porous without cracks, medium clay loam with scattered pebbles; 2) 2-3 to 13 cm light-cinnamon-brown sandy clay loam with pebbles and stones; 3) 13-25 cm brown, more dense and clayey, somewhat finer-textured soil with faded carbonate spots; 4) 25-52 cm pebbles and stones with a small amount of coarse sandy loam with striated gypsum on the pebbles. An analysis showed an insignificant amount of humus (0.3%), a very large carbonate content with the minimum associated with the most clayey horizon, and a considerable accumulation of clay in the middle of the profile, several times more than in Profile No. 2. The finer-textured soil of this desert is characteristic (Table 2).

After 120-150 km, the desert is replaced by desert steppe landscape. The vegetation becomes denser, there is less saltwort and more ephemerals. In the vicinity of Persepolis the elevations acquire quite soft outlines since they are covered with stone clay loams with ephemeral vegetation. The monumental engineering works of Persepolis which are made of siliceous shale are coated with a weathered rosy cinnamon-brown clay surface film.

Profile No. 12 which was taken in the middle of the journey between Persepolis and Shiraz on a comparatively gently sloping proluvial talus gives an idea of the soils of these deserts. The vegetation is wormwood-ephemeral with thorny bushes consisting of Astragalus, Gypsophilia, and others. Bulbous meadowgrass, desert sedge, wild barley and others form a good sod layer in spite of the large amount of stones and pebbles. The following characterized the profile: 1) 0-10 cm a sod-covered, light, gray cinnamon-brown coarse clay loam, blocky, coarse-grained soil with calcified stone; 2) 10-30 cm reddish-brown medium clay loam, more dense, with large nut-shaped aggregates, and with carbonate traces; 3) 30-45 cm brown, fine clay loam, blocky, with carbonate white-flecks and concretions; 4) 45-75 cm straw-colored or white with cinnamon-brown spots, strongly calcified with carbonate lumps, and very dense. It is natural that this soil should have more humus (1.6% in the 0-10 cm horizon). The CO_2 content is still greater than in Profile No. 5 and reaches enormous values (24-38%); the smallest quantities are associated with the reddish-cinnamon-brown horizon. Just as in Profile No. 5, the strongly-marked clayey nature of the middle Profile is characteristic and the fine earths have a fine texture (Table 2). Thus the soils of the deserts and the desert steppes of southern Iran have much in common, particularly in the mineral part of the soil mass.

Owing to incomplete processing of the materials and the lack of factual data, it is difficult to classify these soils into any genetic group. Therefore, they are given arbitrary names in Table 2. One can only say with sufficient justification that the subtropical character of soil formation in the deserts and desert steppes of southern Iran has a completely defined character which is more outstanding than in the sierozem zone of central Asia. In this connection, it is natural that the soils of this part of Iran should show some indications inherent in gray cinnamon-brown soils: a cinnamon-brown tone in the color, the clear-cut clayey nature of the profile, the comparatively fine-texture (in the presence of a course substrate) calcareousness from the surface, and elements of a nut-like structure. The correctness of that which has just been stated is confirmed by the descriptive data of Profile No. 10 taken on a high terrace on one of the small rivers between Persepolis and Shiraz. This Profile showed that the cultivated layer created by irrigation agriculture, with a thickness of 58 cm, is underlaid with the remains (the B horizon) of the former natural soil with a cinnamon-brown color and a clayey texture, clay (23-28% of the particles <0.001 mm in diameter) with a nutty structure, with large spots of carbonate white-flecks, i. e., with features characteristic of gray cinnamon-brown soils. In an article recently published by Beckett (5), the soils of the Kermanshah Basin are called "reddish desert soils," which agrees with our observations.

Unfortunately, it was not possible to familiarize ourselves with the soils of the mountain elevations. However, observations made during the flights from Teheran to Isfahan and from Shiraz to Teheran created an impression of their extreme xeromorphism and

Table 2

Several chemical and particle-size analysis of the fine earths from southern Iran, percent[a]

Profile No. and name of soil	Depth, cm	Humus	CO_2	Size of fractions, mm			
				Sand 1 – 0.05	Silt 0.05 — — 0.001	Clay < 0.001	Physical clay < 0.01
I — 5. Desert straw colored-cinnamon-brown, sandy-medium loam, coarse texture	0—2	0.32	21.0	44.7	40.1	8.2	30.4
	2—13	[illegible]	20.6	76.0	32.3	11.7	[illegible]
	13—24	[illegible]	15.8	46.6	30.0	23.4	41.4
	40—50		23.1	77.5	16.7	5.8	13.2
I — 12. Desert steppe reddish-cinnamon-brown, powdery medium loam, coarse texture	0—10	1.60	[illegible]	35.5	[illegible]	8.0	29.7
	15—25	1.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	35—45	0.69	23.2	32.7	[illegible]	19.0	45.4
	50—60		38.3	[illegible]	[illegible]	[illegible]	22.0
I — 10. Gray-cinnamon-brown, deeply cultivated, powdery, coarse texture	5—15	2.87	16.0	[illegible]	[illegible]	9.3	[illegible]
	30—40	1.40	15.5	[illegible]	[illegible]	[illegible]	[illegible]
	60—70	[illegible]	15.2	[illegible]	[illegible]	[illegible]	[illegible]
	90—100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]—150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Analysts: A. V. Kozlova (humus); V. A. Moldodtsov (CO_2 and particle size). Methods for determinations were same as previous.

the predomination of craggy relief forms. Forest vegetation was not seen; in the best case one could speak of individual juniper trees and of sparse xerophyte bushes. A predominance of wormwood associations of various character was noted. The landscape was enlivened by small irrigated oases with greenery which were associated with narrow mountain valleys and proluvial talus with a strongly branched network of underground streams. The elevations in the vicinities of Shiraz, Persepolis, and Fars were somewhat richer in vegetation; they were less craggy and the slopes were gentler. Fields under dry farming crops were seen in one place. However, forest vegetation was not observed here either. Sharp, craggy spines and cuestas almost devoid of vegetation protruded quite frequently from the stone and pebble foothill valleys.

In general, the results of these excursions can be formulated in the form of the following propositions:

1. The chernozem-like, chestnut, and brown forest soils on the mountains previously shown on the soil maps compiled by Soviet authors must be assumed to be entirely non-existent.[2] The possibility of the formation of the following on the upper portions of the vertical zonality are not excluded: cinnamon-brown forest, gray cinnamon-brown, and dark sierozems. An important, and in some places [illegible] [illegible], apparently belongs to the little-studied soils with thorn bushes and Pulvillus, a situation like that observed in the southern parts of central Asia and the Transcaucasus.

2. In bioclimatic conditions the lower parts of the Iranian Plateau and the adjacent regions belong to the deserts and desert steppes of the subtropical zone, but differ in the character of the soils and vegetation.

3. The northern parts of these areas are close to the landscape of the deserts and desert steppes of central Asia. The chief peculiarity which distinguishes them from the latter is the sharp predominance of stone and pebble deposits. Apparently, the denuded valleys of the "kyr" type, characteristic of central Asia, are also absent here. Saliferous rocks of the Tertiary Age are comparatively rare. The weakly developed accumulation of gypsum in the automorphous desert soils is connected with this in part. Within the limits of the inspected territory we observed stone- and pebble thin-varieties of ordinary (typical) light sierozems and desert sierozems (grayish-brown soils in another terminology). In spite of the coarseness of their texture and thinness, they are used in agriculture on a far greater scale than in central Asia.

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[2] Naturally we are not concerned here with the forest regions of the northern slopes of the Elbrus System, also the eastern part of northern Iran.

4. Midway between Isfahan and Shiraz we noticed a transition to desert and desert steppes of the southern type. More favorable hydrothermal conditions in connection with large precipitation make possible the better development of vegetation and promote the activity of weathering and soil formation, even under the conditions of a stone pebble substrata. This is reflected in the character of the soils which acquire cinnamon-brown and reddish colors, become finer-textured and contain more carbonates as compared with the sierozem soils of northern Iran. These new qualities of the soils are manifested most clearly in the desert steppe zone of southern Iran where such heat-loving crops as oranges are raised with the aid of irrigation. All this points out the necessity for discriminating between the northern and the southern deserts and desert steppes in the character of the soils and vegetation. The problem of the typology of the soils of the deserts and desert steppes of southern Iran is still not clear and requires further investigation.

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DISCUSSION

BROWN FOREST SOILS IN THE USSR, EUROPE, AND THE USA

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In the fall of 1958 at Zagreb (Yugoslavia) luring the International Conference on Probems of the Genesis, Classification, and Geography of Soils of Southern Europe, we were ible to become acquainted with the protocol of he meeting of the Correlation Committee for he Soil Map of Europe, which took place in Ghent (Holland) in May, 1958. The committee s attached to the European Commission on Agriculture (Subcommission on Land and Water Use), which is a part of the FAO (Food and Agricultural Crganization). The mission of he committee is to correlate the major operaion of compiling a new international soil map of Europe.

The committee received legends for the soil nap of Europe from a number of countries as vell as a copy of a manuscript on a world soil nap (for Western Europe on the scale :1,000,000) with a descriptive legend prepared several years ago. Unfortunately, the latter naterial is not further outlined in the protocol. A major portion of the plans for legends presented by different countries are in the form of soil listings with short explanations. We will report some of these proposals.

It is proposed that nine major and about hirty lesser soil subdivisions be used in the soil map of France. Included in the basic sublivisions are: podzolic, soils, brown loessial and loessial; brown Mediterranean non-podzolics, calcareous, recent (alluvial, eolian, etc.); hydromorphic, saline, skeletal.

For the soil map of Italy the number of the najor soil subdivisions is approximately the same. They include: podzolic soils, brown oessial and loessial, brown, brown Mediterranean of the arid forests, brown Mediterranean of mesophytic forests, black Mediterranean, humic calcareous of the high Appenines, alluvil, hydromorphic, saline, azonal terra rossa on limestone, latosols.

The number of principal subdivisions for the soil map of England is increased to fifteen. These are: brown forest, brown forest with low base content, brown forest with weak gleying, gray-brown podzolic, podzolic below 200-600', gley below 200-600', podzolic and gley above 200', peat podzols above 400', alpine humic soils, peats on hills and in lowlands, alluvial, alluvial-gleyed, calcareous, lithosols and thin podzolic, and regosols.

For West Germany the number of soil groups increases to thirty-seven. Included are: rendzinas, terra fusca and terra rossa, pararendzinas, chernozems, degraded chernozems, brown earths, podzolized brown earths, para-brown earths, pseudo-gleys, podzols, river, marsh, bog, and other soils.

It is stated in the protocol of the correlation committee that the data presented "differ from one another by a very distinct degree of detail." However, even the sketchiest comparison of the presented lists indicates that the differences in the legends are not merely those of detail. Discrepancies are much deeper; they involve both the nomenclature of principal soil groups and the very nature of genetic theories and definitions.

This, first of all, concerns the most widely distributed soils in Europe; the brown forest soils. Actually, in the legend for the soil map of France there are three principal subdivisions of brown forest soils; brown, brown loessial and loessial. For the territory of Italy, in addition to these three subdivisions, two groups of brown Mediterranean soils (dry and mesophytic forests) are shown. In the area of England four groups of brown soils, in little agreement with the French and Italian, are distinguished; brown forest, brown forest with low base content, brown forest with weak gleying, and gray-brown podzolics. Finally, in West Germany the number of principal brown soils increases to five, and here again there is a lack of agreement with other schemes. The five groups of German brown earths are: brown earths, podzolized brown earths, parabrown earths, loess, and pseudo-gleys.

From this it appears that one of the chief difficulties in the international compilation of a soil map of Europe is the differing views of soil scientists about the concept of "brown forest soils," the latter's relation to the classical concept "podzol" and the new terms "loess" and "psuedo-gleys," as well as the printiples of classification and nomenclature of these soils.

Apparently the directors of the compilation clearly recognize this principal difficulty. This is indicated by the special review prepared in 1957 by the Belgian soil scientist; R. Tavernier and co-author G. Smith, entitled, "The concept of braunerde (brown forest soil) in Europe and the United States." The review is of considerable size (more than 80 printed pages). It begins with an introduction in which Ramann's views about brown earths are outlined and in which are presented short historical reviews of the concepts of brown forest soils in Central and Eastern Europe, the Scandinavian countries, the British Isles, Germany and Austria, France and neighboring countries, and, finally, the United States of America. In the second part of the review the authors' views (based on their own observations and data from the literature) are presented for the division and principal kinds of brown forest soils and their geographic distribution. The review includes characteristic analytical data and schematic distribution maps for the main groups of brown forest soils in Europe and the USA. It ends with a short, general conclusion. In general the short historical reviews on ideas concerning brown forest soils in different countries are substantial and interesting. These are written very conscientiously, and a misfortune rather than a fault is the fact that language difficulties in certain instances did not allow the necessary soundness. Of course, most disappointing was the omission of Russian soil literature, which abounds in the leading works on soil science not only in the old pre-revolutionary era but also in the recent Soviet period.

In Tavernier and Smith's review most of the attention with respect to Russian works was devoted to the views of K. D. Glinka. The authors try to trace the evolution of this great Russian soil scientist's views on brown forest soils. They note that for a long time Glinka did not consider brown forest soils as an independent genetic group of soils; he included these soils with a group of podzolic soils or degraded chernozems, although he had described (for example, in the vicinity of Novo-Aleksandriya) very typical profiles of brown earths soils with textural horizon B, characteristic tongue-like of horizon A_2 and with the well developed peculiar clay horizon, now called "fragipan" by Americans (see below). According to the authors of the review, only in his work of 1914 did Glinka begin to consider the West European brown forest soils as a special stage of the acid podzolic process of soil formation, expressing a transition from podzols to krasnozems.

Afanas'ev (1922) and Vilenskiy (1927) are mentioned. Their views, according to the review, coincide with the opinion of Glinka that the brown earths of Ramann are "simply chernozems, degraded under forest vegetation" (14, p. 225).

Of the more recent works of Soviet soil scientists on the genesis and geography of brown forest soils, the works of Mikhaylovskaya (1937), Neganov (1938), Gulisashvilli (1942), Liverovskiy (1948), and Rozov (1954) are mentioned. However, in essence, only the work of Liverovskiy (7) is presented, with respect to which it is noted that Liverovskiy "introduced the term Bleached Brown Forest soil" for soils having the textural horizon B, and the term "Podzolized Brown Forest soil" for those soils in which an illuvial sesquioxide horizon is shown. The name of Rozov (1954) is mentioned incidentally in a short review of classification of USSR soils, published in "Pochvovedeniye" in 1952 (on the basis of a German reference). It is said that Rozov, according to the work of Gerasimov, makes a distinction between podzolic, gray and brown forest soils, and also the division of cinnamon-brown soils, which are "peculiar brown soils of dry mountain areas." According to the authors of the review, these soils "resemble the Mediterranean brown soils."

From the foregoing it is clear that in their review Tavernier and Smith could not utilize fully the very valuable data and views of Soviet scientists with respect to the brown forest-soils of Europe and the USA. The works which they cite (except for the work of Glinka and Liverovskiy) are not basic for the soils examined. Indeed, the classic works of L. I. Prasolov on brown forest soils (brown earths) were not mentioned at all in the review. Furthermore, in 1926-1929, L. I. Prasolov (with the partial collaboration of I. N. Antipov-Karatayev) published a series of articles and summaries based on field investigations and devoted to the brown forest soils of the Crimea and the Caucasus. Very important scientific ideas were set forth in these works.

Thus, for example, in the summary "Brown Earths of the Crimea and Caucasus" (8), Prasolov pointed out that "the work of the Crimean Soil Expedition of the Academy of Sciences (beginning in 1925) and everything that is known about the forest soils of the Caucasus indicates that the group of brown earths (of Ramann) is very clearly evident here and quite widely distributed...". And further... "the forest soils of the Crimea are in general clearly distinguishable from northern podzolic soils and from soils of the deciduous forests of our central forest-steppe zone, although it can be said, they blend with them in certain peripheral transitions." On the basis of field investigations n the Crimea, Prasolov distinguished two main subgroups of brown forest soils: 1) "dark-brown forest soils with a large blocky structure without signs of podzolization" and 2) "light-brown or yellowish forest soils with weak signs of podzolization and differentiation of horizons." The latter soils he called podzolized varieties of brown earths.

In 1947 Prasolov published another major work on the brown forest soils of the Caucasus n which he generalized much data from the iterature and field observations (9). He noted he following principal genetic features of brown forest soils: 1) relatively intensive weathering of primary minerals and the formation of secondary minerals; 2) concentration of iron and aluminum; 3) relatively weak development of podzolization; 4) exchangeable acidity, due not only to the hydrogen ion, but also to the aluminum ion; 5) accumulation of well decomposed humus of the "mull" type.

In the previously-mentioned work of Livérovskiy the brown forest soils of the Caucasus and he Far East are characterized. Confirming he principal genetic features of these soils, ndicated by Prasolov, the author of the paper makes an encompassing comparison of brown forest soils with gray forest soils and also analyzes the role of parent material, composition of vegetation, and climate in the formation of brown forest soils. The principal results of his analysis are:

"1. Brown forest and gray soils are similar but nonetheless different types of soil formation. They develop in different (climatic) facies of the xerothermal (southern temperate — I. G.) zone.

"2. The process of brown earth formation attains its typical maximum development in some instances in the zone of mesophytic broad leaf forests..., but mostly in the zone of mountain coniferous and coniferous-broadleaf forests, especially on parent material rich in primary minerals. In the zone of meso-xerophytic forests, mixed and coniferous-broadleaf, brown soils alternate in some cases with podzolized brown soils... or various gray forest soils."

In this short article it is not possible to provide more of a summary of the great number of Soviet soil scientists' work containing valuable materials on brown forest soils. Such a review can replace to some degree the indication that for purposes of preparing modern soil maps of the USSR it has long since been decided o divide the genetic group of brown forest soils nto four principal subgroups, namely typical (saturated) residual calcareous, unsaturated and podzolized brown forest soils. Just such division of brown forest soils is proposed in he article by N. N. Rozov, mentioned in Tavernier and Smith's summary. However, special comments on this system of dividing brown forest soils were provided not by N. N. Rozov, but by V. M. Fridland (12). The latter pointed out that mountain-forest brown typical soils located in the Caucasus have the following characteristics: "Clearly evidenced in their texture is a decrease from bottom to top of the amount of coarse (sandy) separates and an increase in the amount of fine (silt) separates, associated with the weathering processes taking place in these soils (clay formation — I. G.). The uniform distribution of clay in the profile indicates the absence of podzolization. The amount of humus in the upper portion of the profile varies between 4%-5% and 10%. Lower down its content decreases noticeably. Soil reaction is weakly acidic, adsorption capacity is 10-20 meq per 100 g of soil, and increases upward; the adsorbing complex is somewhat unsaturated (adsorbed hydrogen and aluminum make up more than 20%-25% of the exchange capacity). The movement of sesquioxides along the profile is not observed." The brown forest residual calcareous soils, according to Fridland's description, are similar in their properties to the typical, but, being developed on calcareous parent materials, they possess a neutral (upward) and alkaline (downward) reaction. Brown forest unsaturated soils have a strong acid reaction (pH 4-5), and a very large nonsaturation of bases (50%-90%). Their humus has a coarser character and a very wide C:N ratio. These soils develop in districts of the Caucasus with a climate of higher humidity. Finally, the brown forest podzolized soils show clear signs of the development of the podzolic process (differential profile, movement of clay and sesquioxides). They develop among the typical and unsaturated brown forest soils in different districts of the Caucasus, being evidently coordinated with non-detrital and slightly-detrital soil-forming parent material and more uniform elements of relief. This subgroup of brown forest soils is related to other subgroups by gradual transitions.

It is impossible to conclude a short examination of the works of Soviet soil scientists on brown forest soils without pointing out certain investigations devoted to related soils. Among such soils we should first of all mention the so-called acid, forest, non-podzolized soils or "northern brown earths" in the Middle Urals, first described by Ivanova (6), and later by authors in other northern regions. These soils, developed under taiga vegetation in conditions of a cold, humid climate in the northern European part of the USSR, have a brown (often rusty) coloring, an unstable blocky structure and an undifferentiated profile. They are extremely acid, unsaturated and, according to analytical chemical data, are characterized by virtual general impoverishment of silica, and oxides of iron and aluminum, in comparison with the parent material. The impression is created that these soils are totally podzolized — their entire thickness is an eluvial podzolic horizon and the conditions do not exist in its limits for the fixation and accumulation of the decomposition products of the mineral substance (i. e. the formation of an illuvial horizon). This presentation of ours on the genesis of these soils requires verification.

In a recent investigation of the forest soils of the most western Transcarpathian part of the Ukraine (N. B. Vernander, V. M. Fridland, Ye. N. Rudneva) attention was focused on still another special group of brown forest soils, developed principally on loess deposits under deciduous forests. These soils have a well-differentiated profile (with movement of clay particles) of podzolic character, complicated by clearly developed evidences of gleying, appearing on the boundary of the division of upper (lighter) and lower (heavier) parts of the profile. In studying the chemical composition of the clay separate of Transcarpathian soils it was established that it has a quite stable $SiO_2:R_2O_3$ ratio.

In this manner these soils, originally called podzolic-brown earths or even yellow earth-podzolic, were later compared with soils of the group "loessial" described in Western Europe. The author of this article, having examined the problem of the genesis of these soils in a special review (3), proposes to call them brown forest pseudo-podzolic soils. With the use of this term the superficial resemblance of these soils to real podzolics is noted, but along with this their inherent genetic difference is emphasized. The non-descript term "loessial" or "pseudo-gley" contribute nothing to this sense and for this reason seem less successful. The first of these is, in addition, difficult to translate into Russian.

After this short review of Soviet soil science literature we again turn to the review by Tavernier and Smith.

As was indicated previously, the second part of their review (following the survey of the literature) is devoted to an exposition of the authors' own views on the different kinds of brown forest soils and their distribution. This portion begins with the following statement: "It is very apparent from the above review of the literature that, from the start, there has been confusion about the Braunerde and the Brown Forest soils. The ideas about both their genesis and their morphology have been at sharp variance" (14, p. 244). Because of this the authors undertook a selective field study of typical profiles of various brown forest soils of European countries and a comparison of them with soils of the USA, along with a critical review of the literature. As a result of this work they concluded that in Europe and the USA there are only four clearly distinguishable kinds of brown earths or brown forest soils common for all countries, which can be further subdivided into two or more great soil groups. As Tavernier and Smith assume, the differences between the subdivided or principal kinds of brown forest soils are fundamental and are not determined by subjective views of the morphology and genesis of the soils. These four kinds of brown earths are:

1. Soils having horizon (B). 2. Brown podzolic soils. 3. Dark-colored soils bordering the steppes. 4. Gray-brown podzolic and great soil groups related to them having an illuvial horizon B with clay accumulation.

Below we have briefly characterized each of these kinds of brown forest soils on the basis of data presented in the review by Tavernier and Smith.

Soils Having Horizon (B)

The symbol "B" in parentheses was proposed by Laatsch (1938) for a horizon formed by chemical weathering and oxidation of iron without illuviation.[1] Tavernier and Smith include in this class of soils: brown acid soils (Sol Brun Acide) and base-rich soils. Brown acid soils, which are also called brown earths of low base status, are characterized by a poorly differentiated morphological profile, acid reaction, little observable clay migration, and considerable humus accumulation. In Western Europe and the USA they develop in very humid (particularly mountainous) regions, mainly on acid parent materials. In the USA these soils were earlier combined with brown podzolic or gray-brown podzolic soils.

Brown Soils with Horizon (B) Rich in Bases

These are developed on calcareous parent materials. They possess a slightly differentiated profile, weakly acidic and neutral reaction. In Western Europe and the USA they are often called simply brown forest soils.

Brown Podzolic Soils

Included in this class of soils are brown forest soils with evidences of podzolization development. Such evidences can be developed in various degrees, and so slightly that the dividing line between brown podzolic and brown acid soils becomes indistinct. Because of this,

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[1] An analogous proposal was described in the Soviet literature by N. A. Dimo for the brown horizon of gray-brown desert soils (structural sierozems or light earths).

Tavernier and Smith especially point out factors (activity of earthworms, turning over of the soil in windfall of trees, etc.), whereby mixing of horizons A and B and maximization of superficial evidences of podzolization can occur. Special attention was also given to the formation of fine-grained podzols (of a distinct layer under forest litter) on brown acid soils, which on the whole is the reason for relating these to brown podzolic soils. From another point of view, brown forest soils with clearly developed eluvial and illuvial horizons are described, which in their physical-chemical properties are similar to real podzols. However, the degree of podzolization in brown forest soils is always considerably less than in podzolic soils. This is the reason that Tavernier and Smith consider it entirely feasible to use the term "podzolized brown forest soils" for this soil group. Investigators consider that "brown podzolic soils are related to podzols, but distinct from soils with horizon (B). The distinction between soils with (B) and brown podzolic soils is much greater than between the latter and podzolic soils. However, morphological distinctions between brown podzolic and Sol Brun Acide are obscure" (p. 255). Apparently as a result of this, brown podzolic soils in many European countries and in the USA are to this day often not sharply distinguished from brown acid soils.

Dark Colored Soils Bordering the Steppes

The most characteristic sign of these soils is a thick dark horizon A. The dark color usually extends downward to horizon B. The genesis of these dark-colored soils is related to the invasion of forest into steppe regions. The main representatives of the group are: northern degraded chernozems and degraded black soils; degraded brunizems (prairie soils) and reddish prairie soils; degraded chestnut soils, rubrozems. It is still not clear from the data presented in the review by Tavernier and Smith why all the foregoing soil formations are viewed as subdivisions of brown forest soils. Apparently there are two principal reasons for this: in the first place, the existence of gradual transitions from these soils to more or less typical brown forest soils; in the second place, the relation of some of these to brown forest soils (in local soil series in the USA) because they are found under sparse park forests.

Gray-Brown Podzolic Soils

These are treated in much detail in the review by Tavernier and Smith, and are the most wide-spread (among brown forest) soils. They were distinguished by Baldwin and others (1927) as soils having a compact illuvial clay horizon. One of the most typical representatives of these soils in the USA is the Miami silt loam, for which a morphological description and analytic data are given (Table 1).

Of the characteristic morphological features of gray-brown podzolic soils, emphasis is placed on the usual development of fragipan; i. e. a compact, water-impermeable horizon of illuvial-clay character with signs of degradation, powdered-coating, gray-white blemishes, tongue-like horizon A_2, etc. Of the chemical properties, Tavernier and Smith note base saturation (average of 60%) but for some reason they do not discuss the interesting phenomenon of stable colloid composition in clay separate (Table 2).

A reference to the views of Cline (1949, 1950) partially closes the gap. According to these views, gray-brown soils in the region of New York develop from brown forest soils by the progressive leaching of bases and the movement of clay particles. Representing a further stage of development (after gray-brown soils) are the brown podzolic soils whose profile formation is due to the appearance and accumulation in horizon B of free sesquioxides and to the lightening of A horizon. Tavernier and Smith's combination of gray-brown soils with soils of the group "loessial" and "para-Braunerde" described in Europe is indicative of the genetic nature of these soils. It is also important to note that the authors indicated that gray-brown soils in the USA (just as the "loessial" soils in Europe) are very closely related to relatively recent (Pleistocene) calcareous deposits, including loesses and loess-like formations.

Tavernier and Smith also characterize red-yellow podzolic soils and noncalcic brown soils together with gray-brown podzolic soils. The first of these occur in the USA in rather moist and warm subtropical regions (Virginia, New Jersey, Maryland, Pennsylvania). In Europe they are observed in certain regions of the humid Mediterranean (Istria). From the analytical data given it is obvious that they are acid (pH 4-5), strongly unsaturated (4%-20%) clay soils, apparently partially allitized. It is still not clear why, despite their special properties, these soils are listed with the class of brown forest soils. Concerning noncalcic brown soils, their characterization by Tavernier and Smith is less clear. From one point of view their morphological resemblance to gray-brown podzolic soils is noted; from another, it is emphasized that these are typical soils of the Mediterranean climate with a warm, moist winter and a hot summer. In the USA they occur in California, where they possess a characteristic hardpan (compact horizon below B); in Europe they occur throughout the Mediterranean area. Tavernier and Smith quite rightly, in our opinion, contrast these soils with the group of cinnamon-brown

Table 1

Chemical characteristics of gray-brown podzolic soil

Horizon	Depth, inches	pH	Particle diameter, mm		Organic content	CO_2, %	Total Analysis					
							of soil			of colloids		
			0.05—0.002 мм	0.002—0 мм			SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
A_1	0—2	6.3	50.1	15.9	6.22	0.03	74.00	3.28	8.39	41.52	8.84	21.83
A_2	2—5	5.9	50.9	15.5	3.60	0.13	77.81	2.90	8.18	43.10	9.12	23.16
A_3	5—11	5.5	51.1	16.4	1.95	0.09	78.45	3.25	9.57	43.61	10.28	23.82
B_1	11—15	5.3	45.9	22.7	1.37	0.21	76.10	4.05	11.01	44.41	10.94	24.48
B_2	15—30	5.2	28.9	36.9	0.99	0.11	69.80	6.23	14.23	45.10	12.10	24.11
B_3	30—36	6.4	25.7	37.4	1.11	0.16	69.00	6.32	13.99	44.75	12.13	24.27
C_1	36 and greater	7.6	37.1	21.3	0.99	11.28	53.66	4.52	9.99	45.10	12.23	23.87

Table 2

Chemical composition of colloids of gray-brown podzolic soil

Oxide ratio	Horizons and depth, inches						
	A_1 0—2	A_2 2—5	A_3 5—11	B_1 11—15	B_2 15—30	B_3 30—36	C_1 36+
$SiO_2:R_2O_3$	2.57	2.52	2.43	2.37	2.40	2.37	2.42
$SiO_2:Fe_2O_3$	12.52	12.55	11.26	10.70	9.90	9.80	9.93
$SiO_2:Al_2O_3$	3.23	3.15	3.11	3.05	3.17	3.13	3.21

soils of dry forests and shrubs.

If the division of brown forest soils proposed by Tavernier and Smith is compared with the plans for legends for the review soil map of Europe which were presented at the very beginning of this article, and proposed by various countries, then the advantages of the system set forth in the summary seem indubitable. It is based upon a consideration of the actual and most important properties of the various groups of brown forest soils, and for this reason each such group is more or less clearly characterized and can be objectively contrasted with another. It seems at first that the complex and confused problem of classifying the brown forest soils of Europe and the USA is positively solved in the work of Tavernier and Smith and that their system of grouping and nomenclature can be used as an initial base on which to compile a new international soil map.[2] However, a more detailed analysis of their proposals reveals such substantial defects that without removing them the proposals can hardly play their indicated role. The defects relate to the nomenclature as well as to the genesis and geography of the soils under consideration.

If we begin with terminology, we must immediately point out the lack of precision in such important terms as brown acid and gray-brown podzolic soils. Almost all forest soils in all their principal subdivisions are, as is apparent, soils with acid reaction; the only exception can be the relatively slightly developed brown forest soils on limestone with neutral reaction of the upper horizons. For this reason it is hardly suitable to use the term "acid soils" for only one group of brown forest soils. This is a contradiction in fact and logic.

Concerning gray-brown podzolic soils, doubts arise from the use of the term "podzolic." In contemporary European soil literature this term is set off in contrast to the term "loessial." Tavernier and Smith emphasize the genetic affinity of gray-brown soils in the USA and "loessial" soils in Western Europe. But it is necessary to be consistent to the end, and in like manner, many French, German, and other soil scientists reject the addition of the term "podzolic" to gray-brown soils. Certain other terms recommended by Tavernier and Smith are also unfortunate. Among these is the term "noncalcic" brown soils, which in California as the authors themselves indicate, often possess a well-developed calcium horizon (i. e., a horizon with an accumulation of calcium carbonate).

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[2] With the unconditional exclusion of dark-colored soils and red-yellow podzolic soils from the class of brown forest soils.

However, our chief criticisms do not concern questions of terminology, but rather the genetic and geographic treatment of these soils, although, of course, the two are closely related. Genetic questions are insufficiently examined in the work of Tavernier and Smith. Essentially, ideas of the genetic nature of brown earth formation are not presented in this work. The single soil-forming process mentioned in the characterization of brown forest soils is the podzolic process, and even that is done only for the group of brown podzolic soils.

As was noted previously, conditions for the development of the podzolic process and its specific features are not touched upon at all in the investigation of the group of gray-brown podzolic soils. There are even grounds to consider the use of the term "podzolic" here as unreliable.

There are also serious gaps in the genetic treatment of dark-colored soils (often degraded or podzolized), red-yellow podzolic soils (again podzolic), and others. These, in particular, are expressed in such a way that there is no foundation for including them in the general class of brown forest soils. On the whole, we consider that all such gaps of genetic content greatly weaken the entire brown forest soil grouping and nomenclature system proposed by Tavernier and Smith.

The treatment of geographical questions can also be criticized seriously. For example, the principal groups of brown forest soils are divided by Tavernier and Smith into climatic or zonal and intrazonal. To the first acid brown forest soils are assigned as the most northern, brown podzolic and gray-brown podzolic soils, peculiar to warm and drier climates; also noncalcic brown soils or Mediterranean brown earths. To the second group of intrazonal soils are assigned base-rich brown forest soils with horizon (B), derived by the mixing of horizons A and B or developed on calcareous parent material. However, examination of the map-diagrams for the geographic occurrence in the USA and Europe of the various brown forest soils, presented in the outline, does not correspond even to this crude subdivision. Thus, for example, the group of acid brown soils is shown here as mixed everywhere with podzolic, brown podzolic, and gray-brown podzolic soils, and its geographic occurrence in Europe encompasses the territory from England to southern Italy. Brown podzolic soils are shown only in the most northern regions of Europe (southern Scandinavia, northern England) and where gray-brown podzolic soils are absent. But even "noncalcic brown soils" are, in fact, shown principally in the Mediterranean. It seems to us that such lack of clarity in these map-diagrams is explainable not only by the small dimensions of the latter and the sketchy nature of the drawing, but mainly by the author's lack of an accurate geographical conception.

We consider that full utilization of Soviet soil science literature will be of much assistance in the removal of these deficiencies and in the clarification of a series of common genetic and geographical questions concerning brown forest soils. It has been indicated previously that in the review of the cartography of soils in the USSR the division of the independent genetic group of brown forest soils with its subdivisions into typical, residual calcareous, unsaturated, and podzolized subgroups has long been accepted. Soviet soil scientists view the group of brown forest soils as bioclimatic; i. e., as zonal, but consider that in several different conditions of climate and relief and with different parent materials, this group can appear as distinct subgroups. Thus, brown forest unsaturated soils, according to observations, (principally of Georgian soil-scientists) are characteristic of the predominantly western, more humid districts of the Transcaucasus. These soils, and also the brown forest typical (occurring in the northern and central Caucasus), are often associated with brown forest podzolized soils. In the latter, the common genetic signs of the group (increased clay-formation and intensive biological exchange of bases with acid reaction) are combined with superimposed (complementary) evidences of the development of the podzolic process. One of the most important reasons for this combination is the intensification of soil leaching and the weakening of the biological cycle of bases. For this reason podzolized brown forest soils in the USSR develop under conditions of relatively flat relief (diminution of surface-water runoff, increase in infiltration) and predominantly on finely weathered parent materials, relatively poor in cations. Finally, residual calcareous brown forest soils, as their name indicates, are formed on parent materials rich in calcium carbonate.

As was noted earlier, owing to the accumulation of new data, we must now distinguish in southern districts of deciduous forest the occurrence of four more independent bioclimatic genetic soil groups (in addition to brown forest soils), contiguous with brown forest soils in the western part of the USSR: brown forest crypto-podzolic soils; brown forest psuedopodzolic (gley) soils; yellow-brown forest and cinnamon-brown soils of dry forests and shrubs. We shall describe them briefly.

Brown crypto-podzolic soils develop in the upper parts of the forest zone in southern mountains, under mixed coniferous-deciduous forests. They are very acid, unsaturated, usually have a rust-brown color and poorly-differentiated profile. Sometimes, under especially thick forest litter and coarse humic upper horizon, the appearance of thin layers and the lightening of a podzolic horizon, bordering to rust-brown traces is made. It was noted previously that these soils (according to our presentation) are frequently podzolized. Their mineral portion, affected by organic acids, is strongly decomposed, where the decomposition products of alumino- and ferrosilicates (most of all aluminum and iron) in complex organo-mineral substances, reveal high mobility. Owing to the absence of bases and the deep leaching of the soil, the conditions for retaining and accumulating such substances are absent. For this reason these soils, being strongly and deeply podzolized (i. e. decomposed under the influence of organic acids), do not have the typical profile of a podzolic soil of eluvial and illuvial horizons. These soils, accordingly, are crypto-podzolic soils.

Brown forest pseudo-podzolic (gley) soils. If crypto-podzolic soils develop in mountains and further north than brown forest soils (i. e. under conditions of a cooler and more moist climate), then the so-called pseudo-podzolic soils characterized here occur along with the brown. They occur in mountain districts (for example, in the Carpathians) along river valleys and in intermontane basins, in foothills, and especially in the plains of the western part of the USSR. As a rule these soils are associated with slopes and level areas and are developed on friable, predominantly calcareous deposits (loesses, loess-like deposits, etc.). Brown forest, so-called pseudo-podzolic soils, are developed on two-layered deposits, the upper portion of which is sandier and the lower, more clayey. By virtue of this, along the boundary of the upper and lower portion of the parent material, evidences are often observed of water standing and gleying, expressed by variegated coloration (brown and dark blue spots), decolorized tongue-like areas and powder sprinklings, etc. Thus, in the soils being examined, the clay formation characteristic of brown forest soils is superimposed on the two-layered textural (granulometric) profile of the parent material and is complicated by internal soil gleying. Podzolization can also develop here. All this leads to the formation of very distinctive soils with properties similar to podzolic soils in form, but distinct in character. This also gives us the right to call these soils pseudo-podzolic.

Yellow-brown forest soils and cinnamon-brown soils of dry forests and thickets developed in southern mountainous regions of the USSR below (and south of) brown forest soils, under broadleaf forests with an admixture of evergreen woody species. These soils thus represent transitional groups to subtropical soils (red earths and yellow earths). Here the yellow-brown soils are a transition to the moist (humid) subtropics, and the cinnamon-brown — to the dry (arid) soils. The latter groups are the most typical soils of the Mediterranean. In relation to their geographic distribution, yellow-brown soils (in the USSR they are also called yellow earth podzolic soils) are acid forest soils. Along with clay-formation, these soils reveal evidences of some allite formation and development of the podzolic process. On the contrary, cinnamon-brown soils, being neutral and slightly alkaline, have a carbonate horizon and are characterized only by intensive clay-formation. For more detailed questions on these soils special works (1, 4, 11, and others) should be consulted.

Thus, if we again turn to the review of Tavernier and Smith, we may note the comparison of the subgrouping of brown forest soils proposed by these authors and by us:

Our subdivision	Subdivision by Tavernier and Smith
1. Brown forest crypto-podzolic	1. Brown acid (partial) Brown podzolic soils (partial)
2. Brown forest (typical, unsaturated, residual-calcareous and podzolized)	2. Brown acid (partial) Brown soils with horizon (B), base-rich; Brown podzolic soils (partial)
3. Brown forest pseudo-podzolic (gley)	3. Gray-brown podzolic soils
4. Yellow-brown forest (including podzolized)	4. Red-yellow podzolic soils (limited)
5. Cinnamon-brown soils of dry forests and shrubs	5. Noncalcic brown soils (partial)

The mission of future investigations is to clarify the international suitability of the first or the second subgroupings of brown forest and related soils.

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METHODS

A QUANTITATIVE SPECTROPHOTOMETRIC METHOD FOR HUMIC ACID DETERMINATION IN PEAT AND PEAT-BOG SOILS

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The concentration of metals observed in nature (Ge, Cu, Mn, U, Ag, Fe, etc.) in sedimentary rocks and in soils is frequently associated with the presence of significant amounts of organic matter, chiefly humic acids (1, 11, 14, 16, 19). It was shown in controlled experiments that humic acids and fulvic acid form insoluble compounds with metals: with uranium (4), copper (5), aluminum and iron (6), depending on the pH of the solution. These investigations throw light on the problem of the conditions for the migration and concentration of metals combined with organic matter in soils and rocks.

When studying the accumulation of metals by organic substances in soils and rocks, it was essential to determine the concentration of metal as well as the humic acids which form the basis of the organic part of rocks and soils. The determination of the humic acid concentration in peat and peat-bog soils which are to be drained and used in agricultural is also of great interest.

At present there are several methods used to determine the organic substances in soils. The volumetric method developed by Tyurin (7, 8) is used to determine the organic carbon content in soils. The composition of humus is determined (9, 10) by fractional separation of substances extracted from the soil by a mixture of alcohol with benzene, water, alkali, and acid. This method has become widespread and is the only one used to study the constituents of the organic part of soils. Methods to determine the optical properties of humic acids (2) and the threshold of coagulation (3) are effective means to characterize the nature of the humic acids in different soil groups.

The application of the Tyurin method (9, 10) to the study of peat and peat-bog soils is complicated by the necessity (for complete extraction of humic acids) for a very lengthy, repeated extraction of peat with a 0.1 N NaOH solution. In this connection, the method suggested by Welte (20, 21) is of great interest. In this method the humic acids are extracted once from the soil by sodium pyrophosphate (1:25), precipitated by sulfuric acid, redissolved in a 0.5 N NaOH solution, and the quantity of the humic acids is determined by spectrophotometry. In contrast to the usual colorimetric methods, spectrophotometry does not require standard solutions.

Welte established that humic acids obey the Lambert-Beer law at certain dilutions, which makes it possible to measure them colorimetrically. In accordance with Springer's views, Welte considers that under natural conditions soils contain a mixture of two humic acids having different colors. These acids are found in different ratios in soils. In a study of numerous absorption specta for mass determinations of humic acid concentration, he selected light with wavelengths of 472 m μ and 664 m μ. In determining the total quantity of humic acids in soils, he used a method involving differences in indices of extinction (E_4-E_6) with two wavelengths instead of direct measurement of extinction at one wavelength, which ensures reduced effect of admixtures. Welte obtained absorption spectra for synthetic humic acids, determined the specific extinctions, and used this work as a basis for the mathematical formulation of the relationship between the extinction coefficients and values of $Q_{4/6}$. The mathematically derived equation for measuring humic acid concentrations is as follows:

$C = A \times E_4 - B \times E_6$ mg/100 ml 0.5% NaOH solution where C is the concentration of humic acids in mg per 100 ml of 0.5% NaOH solution; E_4 is the index of extinction at a wavelength of 472 m μ; E_6 is the index of extinction at a wavelength of 664 m μ; A = 79.9; B = 103; consequently $C = 79.9, E_4 - 103 E_6$.

The constants in this formula were calculated by Welte on the basis of computations nd measurements of specific extinction of rtificial humic acids. He checked and applied his method to determine humic acid concentra-ions in various soils.

Welte produced a table of weights and pectrophotometric measurements of humic cid concentrations. He obtained very close esults (21). As mentioned previously, he sed sodium pyrophosphate to extract humic cids from soils. Sodium pyrophosphate has een utilized by many research workers to ex-ract organic substances and metals from soils 12, 13, 15, 17, 18).

Kosaka and Iseki (15) showed from a study f soils of volcanic origin that, after testing large number of salts, both sodium pyro-hosphate and sodium citrate are good solvents f humic acids.[1]

We used the Welte method to determine the uantity of humic acids in peat and peat-bog oils. Since these soils contain a large amount f humic acids (in some cases as much as 70%), oil samples weighing 1 g were used for analysis instead of 10 g samples) and were greatly di-uted. The measurements were made with an F-4 spectrophotometer and rectangular cell f 10 mm thickness. Accordingly, we made dditional calculations for Welte's basic equa-ion.

Determination of the Amount of Humic Acids

Samples of peat and peat bog soils about 0 x 10 x 20 cm were cut at different depths f the soil profile under investigation. The amples were dried in air, then carefully round and sifted through a double layer of auze. An average sample from which a 1-g ample of soil or peat was taken from analysis with an accuracy of up to 0.001 g) was about 00 g. This sample was placed in a 500-ml onical flask and treated with 250 ml of 0.1 N olution of sodium pyrophosphate for eight ours in a boiling water bath with a reflux ondenser. After this, the contents of the flask ere cooled and centrifuged. Ten ml of the entrifuged solution were transferred by a ipette into a 50-ml conical flask and 60% $_2SO_4$ (by volume) was added in drops until n acid reaction appeared (pH about 1). The recipitated humic acids were separated in a entrifuge, the solution was decanted from e precipitate, the precipitate in the centri-uge test tube was washed by a small amount f 0.1 N H_2SO_4 solution, then centrifuged again. fter separation from the sulfuric acid solu-ion, the precipitate in the centrifuge test tube as treated with drops of a 2% NaOH solution until a neutral reaction was observed, then the precipitate was dissolved in a small amount of 0.5% NaOH solution. The solution was transferred to a 25-ml graduate flask and brought up to the mark with NaOH solution of the same concentration. After careful stirring, the absorption of light was measured with an SF-4 spectrophotometer. Cells with a measured liquid layer 10 mm thick and light with wavelengths of 472 mμ and 664 mμ were used. The index of the extinction coefficient when $\lambda = 472$ mμ and $\lambda = 664$ mμ were substituted in the equation derived by Welte: $C' = 79.9\ E_4 - 103\ E_6$ mg/100 ml 0.5% NaOH.

Since we deviated from the Welte method in using a cell with a 10-mm thickness and since the initial soil sample was 1 g, it was necessary to introduce the correction

$$\frac{C' \times 5}{10}.$$

In calculating the amount of humic acids in percentages of the soil sample, it was essential to take into account the dilution

$$C = \frac{C' \times 5 \times 25 \times 250 \times 100}{10 \times 10 \times 100 \times 1000} = C' \times 0.313$$

In case a dark solution is obtained after the humic acid precipitate is dissolved, it will be necessary to dilute the solution 10 times before measuring. In this case $C = C' \times 3.13$. In case the humic acids are in small quantities, their precipitates are dissolved in 10 ml of 0.5% NaOH solution. Here

$$C = \frac{C' \times 5 \times 250 \times 100}{10 \times 100 \times 1000} = C' \times 0.125.$$

Let us present an example of the calculation:

The sample of peat weighs 1 g; the volume of 0.1 N sodium pyrophosphate is 250 ml; 10 ml of the extract is taken to precipitate the humic acids; the humic acid precipitate is dissolved in 25 ml of 0.5% NaOH, from which 2.5 ml is taken and 0.5% NaOH solution is added until the volume is brought up to 25 ml again. A cell with a thickness of 10-mm is used; E_4 is the index of extinction with a wavelength of 472 mμ with a value of 0.365; E_6 is the index of extinction with a wavelength of 664 mμ with a value of 0.070; the conversion coefficient (taking into account the dilution) is 3.13.

$C' = 79.9 \times E_4 - 103 \times E_6 = 79.9 \times 0.365 - 103 \times 0.070 = 21.95$ ml/100 mg 0.5% NaOH. $C = C' \times 3.13 = 21.95 \times 3.13 = 68.7\%$ humic acids (by the air-dried weight of the peat).

In order to check the accuracy of the determination of humic acid concentration by the Welte method, we made a quantitative separation of the humic acids by repeated (14

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[1] This is associated with the high capacity of pyro-hosphate to form complexes.

(14 times) extractions of peat bog soil in 0.1 N NaOH solution with subsequent precipitation with sulfuric acid (10).

It was established that the same amount of humic acids was extracted from the peat by a single treatment with sodium pyrophosphate (Table 1).

We used the Welte method in studying a large number of cross sections of peat and peat-bog soils after the bogs were drained. It was shown that the amount of humic acids was associated with the degree of decomposition of vegetation residues (Table 2).

The spectrophotometric method suggested by Welte to determine the humic acid content is very rapid and convenient in mass determinations of the total amount of humic acids (precipitated from alkaline solutions by mineral acids) in peat and peat bog soils.

When applied to soils in which the humic acids are combined with the mineral part of the soil in complex forms, however, the method for their quantitative analysis by extraction with a sodium pyrophosphate solution requires further development.

Conclusions

The spectrophotometric method developed by Welte was utilized, with small changes, for the quantitative analysis of humic acids in peat and peat-bog soils.

Table 1

Comparison of humic acid content in peat soil

Section No.	Ash content, %	Extracted with 0.1 N NaOH		Determined by Welte method
		Without preliminary decalcification	After preliminary decalcification	
1	15.30	31.0	33.5	36.0
2	14.02	34.4	35.6	34.0

Table 2

Humic acid content in soil section 1, Kossovo Bog Station (bog drained by a network of of open ditches)

Characteristics of the peat	Depth, cm	Degree of decomposition, %	Humic acid content, % of soil
Heavily penetrated by oat roots, friable, cinnamon-brown color	0—10	30—35	33.3
Sedge and reed peat, dark cinnamon-brown color, heavily penetrated by roots	10—20	30—35	40.0
Sedge and reed peat, dark cinnamon-brown color, with remains of oat roots	20—35	40	41.5
Sedge and reed peat, with remains of reeds, wet, compact	30—65	40—45	46.6
Remains of reeds, slightly decomposed	90—105	25	3.6
Underlying material — sand	105—115	0.0	0.0

The measurements were made with an SF-4 spectrophotometer and with the use of cells with a liquid thickness of 10-mm and with light of two wavelengths — $\lambda = 472$ mμ and $\lambda = 664$ mμ. This method made it possible to perform mass determinations of the humic acid concentration in peat and peat bog soils.

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CHARACTERISTICS OF SOD-PODZOLIC SUPERFICIALLY GLEYED SOILS OF THE NORTHERN PRE-CARPATHIAN REGION OF UKRAINIAN SSR

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Sod-podzolic superficially gleyed soils occupy a large area in Drogobych, Stanislav, and Chernovtsy Oblasts and play a large role in their agriculture. They are very unique in their structure and are distinguished in a number of important respects from the sod-podzolic soils of other regions of the USSR. They have been studied little up to recent times.

Data on the soils of Drogobych and Stanislav Oblasts are lacking in publications by Polish scientists up to 1940 (13) and there are no data on soils of Chernovtsy Oblast' in papers by Rumanian scientists (24, 25). Soils analogous to the sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region of Ukrainian SSR were found by Chernescu (24) in the Carpathian foothills in Rumanian territory and classed under the name of secondary podzols gleyed by surface waters. They are very close, in respect to soil formation and morphological structure, to the soils we are describing but there is almost no analytical data on them by Chernescu. Soils from the Pre-Carpathian foothills with morphological structure and physicochemical properties similar to the soils described here were found by Bogatyrev and Rudneva (2, 17) and classed under the name of superficially gleyed light-brown forest podzolized soils. Some data on the chemical properties of these soils, in particular on the amount of available forms of phosphorus, are given by the Rumanian scientist Sisesti (25).

In 1940-1941 and in 1946-1947 the Ukrainian Scientific Research Institute of Socialist Agriculture made studies in order to compile soil maps of Drogobych, Stanislav, and Chernovtsy Oblasts. The materials obtained in these studies are in manuscript form; they contain little analytical data on sod-podzolic superficially gleyed soils.

A short paper by Skorina (19) on the soils of Chernovtsy Oblast' gives some picture of the sod-podzolic soils of the Pre-Carpathian Region. Unfortunately, the description of these soils and the analytical material on them are not sufficiciently complete.

We made trips to Drogobych, Stanislav, and Chernovtsy Oblasts in 1955 and 1956 with the object of further study of the sod-podzolic superficially gleyed soils of the Pre-Carpathian Region.[1]

Sod-podzolic superficially gleyed soils cover the watersheds of Carpathian foothills at an altitude of 300-400 m above sea level. The relief of the Pre-Carpathian Region is undulating, with narrow watersheds dissected by the valleys of small rivers, and has a general slope from the Carpathians to the Dnestr. Short, gentle slopes with gradients up to 5° predominate. The microrelief formed by ridges with a width of 2-10 m, resulting from continuous plowing in narrow strips, is well developed and very unique. Under excessively wet conditions such plowing made it possible to dry the land and to obtain high yields of agricultural crops.

The Pre-Carpathian Region lies in a zone of temperate, warm, and humid climate. The mean annual temperature is 7-8° C. The lowest temperatures occur at the end of January and the beginning of February, about -3° C, and the highest occur in July-August, about +17° C. The growing season with an average daily temperature $>$ 10° C lasts 160-170 days. Annual precipitation is 600-800 mm, but up to 1000 mm fall in some years. Precipitation exceeds evaporation. The relative humidity is high — 61%-87%. The water table lies at a depth of 12-15 m and deeper.

The sod-podzolic superficially gleyed soils of the North Pre-Carpathian Region were formed on a deluvial clay loam free of carbonates under forest vegetation. In the past the Pre-Carpathian Region was covered with spruce, fir, oak, and beech forests. At present the majority of the forests have been cut down and the land has been plowed. The cut-over areas which have not been plowed are grown over with sparse forests of oak, birch, aspens, and alders. The forest composition has also changed somewhat. The forests consist principally of oaks with a mixture of firs, birches, alders, spruce, and hornbeam. The grass cover of various species is well developed under this canopy.

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[1] The samples were carefully analyzed in the soil science laboratory of Kiev University. Work was done under the supervision of N.B. Vernander.

The predominance in the past of coniferous trees (spruce, firs), the heavy precipitation, the poorly-drained relief, and the non-carbonate soil-forming parent material brought about the development of the podzol-forming process. However, the coniferous species were displaced by deciduous trees with a well developed grass cover and the podzol process of soil formation was replaced by sod, resulting in the formation of sod-podzolic soils. The podzolic process made possible the formation of a dense illuvial horizon almost impervious to water in these soils. Water stood on the ground in the spring when the snow thawed and in the summer and autumn after heavy rains, forming a unique water-logged layer which facilitated the sharp periodic gleying of the upper horizons of the sod-podzolic soils. A description follows of two profiles (forest and field) of the sod-podzolic superficially gleyed soil of Drogobych Oblast'.

Profile 12. Located 400 m east of the farmstead of Rikhtichi Village on a very gentle slope with a scarcely noticeable gradient sloping to he east, with an oak forest. The young growth consisted of hornbeam and buckthorn. There was a thick undergrowth of hazelnut. The grass cover of various species was well developed.

H_0 0-2 cm. Half-decomposed forest litter.

HE 2-13 cm. Gray, friable, silty medium clay loam with a nut-like, silty structure. Bean-like ferromanganese particles and many roots were encountered. The transition was scarcely noticeable.

Egl 13-27 cm. Light-gray, laminated, slightly compact, many bean-like ferromanganese particles. The transition was gradual.

Eigl 27-48 cm. Brownish-white, nut-shaped particles, slightly compacted. Contained a arge quantity of ferromanganese bean-like particles. The transition to the next horizon was distinct.

Igl 48-88 cm. Ocherous brown with dark blue streaks along cracks; dense, sticky, of prismatic and nut-like structure, full of crevices. Contained many ferromanganese bean-like particles.

Ipgl 88-160 mm. Ocherous brown, with ark blue spots and containing ferromanganese bean-like particles, dense, compacted.

Profile 13. Located in a plowed section 1.5 km northeast of Rikhtichi Village in the middle of a gentle southerly slope with gradient up to 2°.

H_{plow} 0-25 cm. Gray, friable, wet, with powdery and blocky structure. The transition was scarcely noticeable.

Egl 25-34 cm. Light gray, slightly compacted, laminated.

Eigl 34-50 cm. Brownish-white, slightly compacted, nut-like aggregates. The transition was noticeable.

Igl 4-86 cm. Brown with ocherous spots, dark blue streaks along cracks, dense, nut-like aggregates. The transition was gradual.

Ipgl 86-170 cm. Ocherous brown, with dark blue strips along cracks, dense, compacted.

Bean-like particles of ferromanganese were found throughout the entire profile, with the largest accumulating in the eluvial horizon.

In soils under forests the upper humus layer had a thickness of 7-12 cm (up to 14) and in the plowed lands it had the same depth as the plowed layer. The lower boundary of the eluvial horizon varied from 26-35 cm from the surface. The illuvial horizon began at depths of 40-55 cm. An eluvial-illuvial horizon lay between the eluvial and the illuvial layers. These soils were characterized by a very scarcely noticeable transition from the sod layer to the eluvial and, on the other hand, a sharp transition from the eluvial to the illuvial horizon. The transition from the illuvial horizon to the parent material was so gradual and unnoticeable that it was really impossible to determine their boundaries. One's attention was attracted by the deep cracks in the illuvial horizon — crevices which went down to depths of 2 m and more. Moisture moved chiefly through these cracks and also along roots. The cracks separated the illuvial horizon into large, columnar sections which were particularly noticeable in exposed areas. The sides of the columns were covered with incrustations of R_2O_3 compounds which were dark blue when wet and dark brown when dry. The morphological structure of the profile of these soils indicates the podzolic character of the soil formation. The processes of periodic gleying (the presence of bean-like particles of ferromanganese, and ocherous and dark blue spots and incrustations through the entire profile) were well defined in these soils along with podzol formation.

The podzolic character of the soils is also confirmed by the history of their formation under the forest canopy. Remnants of the forests under which similar soils are encountered are still maintained to the present time.

The podzolic process is also indicated in the data presented below from the particle size analysis (Table 1) which reveal a marked loss of clay particles from the upper horizons of the soil profile. The amount of clay particles in the illuvial horizon is almost double that of the eluvial. The texture becomes finer with depth and there is a transition from coarse and medium clay loams with coarse silt-like to fine clay loams. The considerable percentage of coarse silt which impair its physical properties is characteristic of the soils described here.

Table 1

Particle size analysis of sod-podzolic superficially gleyed soils (N. A. Kachinskiy)

Profile No.	Depth, cm	Solution from HCl	Particle diameter, mm						
			1.0— —0,25	0,25— —0,05	0,05— —0,01	0,01— —0,005	0,005— —0,001	<0,001	<0,01
12	2—12	1.03	0.5	7	63	11	8	9	28
	15—25	0.60	0.4	8	59	11	10	11	32
	32—42	0.88	0.5	8	58	10	10	12	32
	70—80	1,29	0.5	9	50	7	9	23	39
	140—150	2.13	0.4	8	47	9	9	24	42
13	0—12	1.68	0.8	7	59	10	11	10	31
	25—35	1.29	0.9	9	57	9	11	12	32
	40—50	1.24	0.6	7	59	8	10	14	32
	70—80	1.39	1.10	9	50	8	9	21	38
	150—160	2,11	0.9	9	44	8	8	28	44
2	0—20	2.16	1.0	7	54	8	12	16	36
	24—34	1.92	0.7	10	46	10	10	21	41
	70—80	2.28	0.9	12	39	7	11	27	45
	180—190	2.47	2.4	11	36	8	11	29	48
10	0—15	1.80	0.7	9	58	9	12	9	30
	25—35	0.72	0.9	8	59	8	12	11	31
	40—50	1.03	0.6	7	59	9	9	14	32
	70—80	1.77	0.9	8	53	7	7	22	36
	150—160	2.32	1.2	9	42	11	8	26	45
11	3—15	1.32	0.8	10	58	10	10	10	30
	30—40	1.08	0.5	7	60	9	10	12	31
	42—52	0.74	0.7	8	59	9	9	13	31
	70—80	2,11	0.7	7	52	7	7	24	38
	180—190	1.85	0.8	8	46	9	8	26	43

The data obtained from the total chemical analysis (Table 2) show that the mineral part of the upper horizons of the soil is decomposed to a considerable depth (down to 40-50 cm). As a consequence there has been a relative accumulation of SiO_2 and an impoverishment of aluminum and iron from the R_2O_3 being carried away into deep-lying horizons, also impoverishment of calcium and magnesium. This is also indicated by the molecular ratios of $SiO_2:Al_2O_3$ which have values very close to those of podzolic soils. The periodic gleying of the soils has also contributed to the loss of iron and the enrichment of the upper horizons with SiO_2, along with podzol formation. A number of investigations have been devoted to the problems of the interrelationship of podzol formation and gleying (1, 2, 3, 8). Since the elucidation of this problem requires special investigations and is outside the scope of this paper, we shall not concern ourselves further with it.

The wider molecular ratio of $SiO_2:Al_2O_3$ and the markedly smaller amount of R_2O_3 in the upper layers constitute an important difference between the sod-podzolic soils of the Pre-Carpathian Region and the brown forest soils located somewhat higher in the Carpathians. The sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region differ from soils of the Southern Pre-Carpathian Region by a somewhat smaller R_2O_3 and total manganese content and also by a different ratio of total calcium and magnesium. The soils of the Northern Pre-Carpathian Region contain insignificant amounts of these elements but nevertheless calcium predominates over magnesium everywhere. On the other hand, the soils of the Southern Pre-Carpathian Region, which have an insignificant calcium content according to Fridland (21), have a great deal of magnesium (especially in the upper horizons) which predominates through the entire profile.

Table 2

Total chemical composition of sod-podzolic superficially gleyed soils, % of ignited soil

Place of sampling	Profile no.	Depth, cm	Ignition loss	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	P_2O_5	$\frac{SiO_2}{Al_2O_3}$
Drogobych Oblast', Rikhtichi Village Forest	12	2—12	6,25	75.50	11.10	3.63	7.39	0.083	0.67	0,15	0,083	17,8
		15—25	2.81	79.67	11.14	3.31	7.74	0.079	0.72	0,31	0,085	17,5
		32—42	2.75	79.60	11.50	3.73	7.69	0.074	0,72	0,43	0,083	17,6
		70—80	2.95	74.41	17.41	5.44	11.89	0.082	0.87	0.76	0,078	10.7
		140—150	2.71	74,80	16,49	5.47	10.94	0,072	0,98	0,89	0.077	11,6
Drogobych Oblast', Rikhtichi Village Plowed land	13	0—12	4,24	76.64	12,09	3,68	8.33	0,088	0.89	0,18	0.091	15,6
		25—35	2.96	78.66	11.48	3.74	7.63	0.077	0.85	0,30	0.102	17.5
		40—50	2,65	79.17	12.07	4.15	7.84	0.068	0.87	0.37	0.081	17.2
		70—80	2,52	75.33	18.17	5.88	12.16	0.088	0.89	0,72	0,078	10.5
		150—160	2,85	74.84	16.91	6.31	10.52	0.074	0.94	0.76	0.077	12.0
		250—260	2,86	74.85	16.77	6.30	10.40	0.073	0.91	—	0.071	12,2

The data which characterize the physicochemical properties of the sod-podzolic superficially gleyed soils of the Pre-Carpathian Region are presented in Table 3. The amount of hygroscopic moisture, which is closely connected with the amounts of colloids, indicates that the latter have migrated into the lower horizons of the soil, giving their clayey nature. One's attention is struck by the sharply pronounced acidity of the sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region. The soil reaction throughout the entire profile is acid: the pH value (of a salt extract) is 4.7-4.8 even in the parent material, while it varies from 4.2-4.4 in the upper layers (with the exception of the cultivated treatments, which will be discussed later). The hydrolytic acidity is very high. It reaches 13-15 meq per 100 g of soil in the upper horizons of soils under forests. Such high acidity is found nowhere in Ukrainia except in the Carpathians. The hydrolytic acidity decreases with depth, but does not disappear. Even in the parent material it varies from 2-2.5 to 3 meq. Profile 14 from Chernovtskaya Oblast' where the highest acidity is observed in the illuvial horizon constitutes somewhat of an exception. This is obviously connected with the warmer climate of Chernovtskaya Oblast' and the deeper penetration of the weathering processes. There soils are distinguished by a fairly high exchange acidity and the presence of significant amounts of mobile aluminum, which are likewise observed nowhere in Ukrainia except the Carpathians. The exchange acidity, like the hydrolytic acidity, is highest in the upper horizons and reaches 4-6 meq in soils under forests. It decreases with depth and is 0.25-0.4 meq per 100 g of soil in the 180-190 cm layer.

The distribution of mobile aluminum throughout the profile has been observed to follow the same pattern as the distribution of exchangeable and hydrolytic acidity. The greatest amount of mobile aluminum is concentrated in the upper horizon (it reaches 3-5 meq per 100 g of soil in forest soils); it decreases gradually with depth and is present in insignificant amounts in the parent material, on the order of 0.1-0.3 meq per 100 g of soil.

The sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region are very poor in adsorbed bases; the smallest amount of adsorbed bases is found in the eluvial horizon (< 2 meq). The total amount of adsorbed bases is somewhat higher in the humus horizon as a result of sod-forming process. It also increases with depth from the eluvial horizon to the parent material, where it amounts to 13-17 meq. The

Table 3

Physicochemical characteristics of the sod-podzolic superficially gleyed soils of the Pre-Carpathian Region

Place of sampling	Profile	Depth, cm	Hygroscopic water, %	Humus, % (Tyurin's method)	pH, salt extract	meq, 100 g of soil							Degree of saturation, %
						Hydrolytic acidity (Kappen's method)	Exchangeable acidity and mobile Al (Sokolov's method)			Total adsorbed bases (Kappen-Gil'kovits method)	Adsorbed cations (Geidroits method)		
							Exchangeable acidity	H^+	Al^{+++}		Ca^{++}	Mg^{++}	
Drogobych Oblast', Girovka Village. Field well manured.	1	0—20	4.00	5.54	5.2	4.41	0.25	0.17	0.08	25.12	Not determined		85.07
		23—33	4.69	5.26	5.0	8.65	0.50	0.21	0.29	24.52	"	"	73.92
		45—55	4.00	3.15	4.8	7.44	0.24	0.10	0.14	20.17	"	"	73.05
		90—100	3.46	—	4.9	2.07	0.13	0.08	0.05	14.83	"	"	87.75
		190—200	4.96	—	5.1	1.29	0.19	0.18	0.01	—	"	"	—
Drogobych Oblast', Girovka Village. Field limed.	2	0—20	2.77	2.18	6.1	1.33	0.24	0.35	0.05	17.01	13.75	3.05	90.76
		24—34	3.40	0.77	4.8	3.46	0.50	0.07	0.43	10.68	9.41	2.15	75.53
		70—80	4.88	—	4.6	3.46	0.72	0.20	0.52	14.93	10.68	4.27	81.18
		180—190	4.76	—	4.7	2.16	0.26	0.16	0.10	17.01	14.02	3.46	83.52
Drogobych Oblast', Girovka Village. Field under clover and timothy. Second year.	3	0—20	2.17	2.25	4.4	8.31	1.76	0.11	1.65	4.94	Not determined		37.28
		25—35	2.22	0.76	4.4	7.78	2.83	0.33	2.50	5.53	"	"	41.54
		70—80	4.38	—	4.3	5.19	2.28	0.36	1.92	13.64	"	"	72.43
		180—190	4.47	—	4.7	2.51	0.45	0.18	0.27	16.51	"	"	81.54
Drogobych Oblast'. Mixed forest of oak, hornbeam, and fir.	4	3—10	2.36	4.59	4.4	13.15	4.42	0.33	4.09	2.86	"	"	17.86
		15—25	1.70	0.96	4.3	8.74	5.30	3.21	2.09	1.58	"	"	15.31
		70 - 80	2.95	—	4.2	6.66	3.67	0.91	2.76	8.30	"	"	56.15
Drogobych Oblast', Staroye Village. Plowed land.	5	0—15	2.12	3.02	4.4	9.86	2.63	0.34	2.29	4.45	"	"	31.09
		19—29	2.42	1.23	4.3	9.78	5.21	3.05	2.16	5.24	"	"	34.88
		70 - 80	3.80	—	4.2	5.27	2.15	0.45	1.70	13.25	"	"	71.54
Drogobych Experiment Field. Plowed virgin land, not planted.	10	0—15	2.14	3.20	4.6	7.87	0.78	0.18	0.40	5.93	4.24	1.41	42.97
		25—35	1.81	1.08	4.4	9.95	3.57	0.14	3.43	4.05	2.66	0.98	28.92
		40—50	1.55	0.89	4.4	7.96	2.93	0.38	2.55	3.16	2.15	0.59	28.41
		70—80	3.12	—	4.4	4.50	1.60	0.19	1.41	9.79	7.26	2.74	68.51
		150—160	3.58	—	4.6	2.68	0.42	0.28	0.14	14.63	10.80	3.73	84.57
Drogobych Experiment Field. Young growth of oak on a cut-over area.	11	3—15	2.60	4.64	4.2	15.05	6.25	0.50	5.75	1.78	1.34	0.36	10.57
		30—40	1.90	1.37	4.2	10.73	5.11	0.34	4.77	1.68	1.07	0.30	13.53
		42—52	1.82	0.78	4.3	8.74	3.30	0.27	3.03	3.26	1.76	0.98	27.16
		70—80	3.38	—	4.5	3.80	1.13	0.32	0.81	10.58	6.63	3.88	73.57
		180—190	3.98	—	4.8	2.16	0.30	0.21	0.09	14.53	10.18	4.35	87.05

Table 3 (Continuation)

Place of sampling	Profile	Depth, cm	Hygroscopic water, %	Humus, % (Tyurin's method)	pH, salt extract	meq, 100 g of soil							Degree of saturation, %
						Hydrolytic acidity (Kappen's method)	Exchangeable acidity and mobile Al (Sokolov's method)			Total adsorbed bases (Kappen-Gil'kovits method)	Adsorbed cations (Geidroits method)		
							Exchangeable acidity	H^+	Al^{+++}		Ca^{++}	Mg^{++}	
Drogobych Oblast'. Rikhtichi Village farmstead. Oak forest.	12	2—12	2.12	5.54	4.4	13.44	3.39	0.27	3.12	1.65	1.37	0.29	10.93
		15—25	1.30	1.02	4.4	7.83	3.17	0.11	3.06	0.69	0.63	0.10	8.09
		32—42	1.47	0.77	4.4	8.07	3.12	0.11	3.01	1.12	0.97	0.23	12.19
		70—80	2.83	—	4.3	5.03	1.64	0.11	1.53	9.18	6.41	2.66	62.04
		140—150	2.71	—	4.7	2.74	0.38	0.11	0.27	13.00	9.11	4.02	82.59
Drogobych Oblast', Rikhtichi Village. Plowed land.	13	0—12	1.42	2.15	4.8	4.49	0.12	0.06	0.06	6.95	5.49	1.37	60.75
		25—35	1.48	0.96	4.7	4.11	0.22	0.05	0.17	6.10	4.90	0.98	59.74
		40—50	1.52	0.78	4.7	4.11	0.28	0.06	0.22	4.51	3.81	0.76	52.32
		70—80	2.46	—	4.6	3.45	0.58	0.08	0.50	9.07	6.56	2.06	72.44
		150—160	3.31	—	4.7	2.17	0.20	0.09	0.11	13.74	9.64	4.36	86.36
Chernovtskaya Oblast', Vinnitskiy Rayon, Maydan Village. Abandoned land for 3-4 years.	14	0—10	2.78	3.19	4.6	6.81	0.54	0.11	0.43	5.89	Not determined		46.38
		13—23	2.44	1.19	4.3	6.32	1.67	0.06	1.61	3.24	"	"	33.99
		23—33	2.51	0.66	4.2	9.06	4.05	0.06	3.99	3.98	"	"	30.52
		70—80	5.29	—	4.0	14.53	8.01	3.09	4.92	9.61	"	"	39.81
		130—140	4.99	—	4.1	7.76	3.26	0.21	3.05	14.38	"	"	64.95
Stanislav Oblast', Kalushskiy Rayon, Myslov Village. Plowed land.	15	0—10	2.35	2.78	4.5	6.13	0.42	0.06	0.36	5.57	"	"	47.60
		28—38	1.79	0.79	4.3	5.57	1.84	0.04	1.80	3.03	"	"	35.23
		42—52	3.59	—	4.2	7.42	2.87	0.08	2.79	7.80	"	"	51.25
		70—80	3.74	—	4.2	5.01	1.54	0.07	1.47	10.14	"	"	66.93
		140—150	3.85	—	4.5	2.50	0.26	0.07	0.19	13.74	"	"	84.60
Stanislav Oblast', Stanislav Rayon, Zsgvozd'ye Village. Plowed land.	16	0—10	2.36	2.31	4.7	4.08	0.11	0.05	0.06	7.27	"	"	64.05
		22—32	2.30	1.02	4.5	4.68	0.55	0.01	0.54	6.32	"	"	57.45
		33—43	3.64	0.54	4.4	4.83	0.71	0.06	0.65	8.65	"	"	64.17
		70—80	4.83	—	4.4	3.71	0.40	0.07	0.33	13.05	"	"	77.86
Same as above, on a cut-over area grown over with oak, birch, and hornbeam.	17	0—7	2.88	4.29	4.4	10.51	1.99	0.09	1.90	3.99	"	"	20.62
		15—25	1.97	1.64	4.4	6.63	1.94	0.07	1.87	2.18	"	"	24.74
		30—40	2.22	0.80	4.4	4.85	0.63	0.03	0.60	4.83	"	"	49.89
		70—80	4.16	—	4.5	3.92	0.27	0.05	0.22	13.75	"	"	77.82

high hydrolytic acidity and the lack of adsorbed bases cause the extremely low degree of base saturation of these soils. Even at depths of 180-190 cm the degree of saturation does not exceed 86%-87% while it varies from 10%-20% in the upper horizons with the minimum in the eluvial horizon. It can be seen from the data presented here that the parent material itself is acid and unsaturated which, of course, is reflected in the formation of the soil. The humus content is highest in forest soils where it reaches 4%-5% in the upper horizon. The amount of humus drops sharply and amounts to 0.7%-1.5% at a depth of 15-25 cm. In spite of the fairly high humus content, the upper humus-containing horizon has a light color which is obviously caused by the predominance of fulvic acids in the humus.

Table 3 gives some idea of the chemical characteristics of the soils described here.

The sod-podzolic superficially gleyed soils of the Pre-Carpathian Region contain small amounts of total phosphorus (Table 2) but their fertility is affected particularly by the lack of available forms of this element (Table 4) which are combined with R_2O_3 in compounds not readily available to plants. The lack of available forms of phosphorus is particularly pronounced in forest and little-cultivated soils, therefore the application of phosphorus fertilizers to these soils is an essential measure.

There is a great deal of hydrolyzed nitrogen in the soils, which confirms the presence of a large amount of available fulvic acids. Nitrification processes are greatly suppressed, especially in soils under forests, owing to the high acidity and the periodic excess of moisture. Ammonification processes are more active since a certain amount of ammonia nitrogen is accumulated in the soils.

It is necessary to mention that man's economic activities have had a very great effect on the soils of the Pre-Carpathian Region. In order to obtain any harvests at all from soils of low fertility, the peasants have been plowing in ridges and strips for a long time to conserve run-off. Moreover, they applied large amounts of manure, limestone, poultry droppings, and ashes to the land; the majority of the population worked small narrow strips of land and everyone applied as much fertilizer to the land as he could. Therefore, the sod-podzolic soils of the Northern Pre-Carpathian Region are distinguished by their exceeding variety in the degree of cultivation. Soils of very greatly different fertility are encountered in a single small section of land.

If we compare the data for Profiles 1, 2, and 3 taken from a section of the Girov Agricultural School and Profile 4 taken from a forest not far from the first site, then the effect of fertilizing and liming on the properties of the soils described here becomes quite clear. By 1945 all the plowed soils had approximately the same fertility and the same degree of cultivation. The section from which Profile 1 was taken received 60 metric tons of manure/ha in 1945-1946-1947; 15 in 1948 and 1952; 20 in 1953; and 6 tons of limestone/ha in 1950. The section from which Profile 2 was taken received no manure, but did receive 8 tons of limestone/ha in 1946 and another 8 tons/ha in 1953 while the section from which Profile 3 was taken received 4 tons of limestone/ha.

As may be seen from the figures in Tables 2 and 3, the application of manure not only increased the humus content in the soil but its distribution in the profile became different. The soil is deeply colored by humus and the humus content is 3% even at a depth of 45-55 cm. The increase in the amount of organic substances in the soil was accompanied by an increase in the nitrification capacity and in the amount of available P_2O_5. However, the application of manure alone, even in the large amounts used on the section mentioned here was not enough — it was necessary to apply limestone to the soil in order to decrease the acidity. Liming (Profile 2) reduced the amount of mobile aluminum and exchange acidity to almost nothing, the hydrolytic acidity was sharply decreased, the reaction became almost neutral, the nitrification capacity and the degree of base saturation rose sharply, and the amount of available phosphorus was increased. The section from which Profile 3 was taken remained lightly cultivated, with high acidity, low humus and adsorbed base content, and weak nitrification. According to figures of the Drogobych Experiment Field, the potato yield in the soils described here, averaged over three years, amounted to 103 cntr/ha without fertilizers, increased to 150 with the application of 20 metric tons of manure/ha and up to 177 cntr/ha with the application of 20 tons of manure/ha with mineral fertilizers (with 45 kg/ha each of N, P, K - N, and P and with 60 kg/ha of K). The yield of winter wheat increased from 6.5-14.8 cntr/ha with the application of 20 metric tons of manure/ha.

It is essential to apply organic and mineral fertilizers and limestone at the same time. Liming can be done in large doses of 6-8 metric tons/ha once per crop rotation or in doses of 1 metric ton/ha annually. The 40 Year October Kolkhoz of Bogorodchanskiy Rayon, Stanislav Oblast', obtained an increase of 4 cntr/ha in its wheat harvest when 15 metric tons of well-rotted manure, 5 cntr/ha of crushed limestone, and 2 cntr/ha of superphosphate were applied to the land. Lupine, which had not been used here previously, is giving good results as green manure. When lupine was plowed under as green manure, the potato harvest was increased from 103-104 cntr/ha in the Drogobych Experiment Field. The Chernovtsy Experiment Station is now growing seed for perennial lupine, which

Table 4

Available phosphorus, hydrolyzable nitrogen, and biological activity in the soils under study

Place of sampling	Profile No.	Depth, cm	P_2O_5 (available), mg/100 g (Arrhenius method)	Hydrolyzable N, mg/kg (Tyurin and Kononova method)	Biological activity			
					NO_3, mg/kg		NH_4, mg/kg	
					Before test	After test	Before test	After test
Drogobych Oblast'. Plowed land	1	0—20	22.5	Not det.	1.008	18.62	2.97	2.78
		23—33	6.0	"	0.561	1.06	8.93	10.93
		45—55	10.5	"	0.515	0.489	3.25	2.27
Same	2	0—20	25.5	"	0.617	22.16	3.25	1.99
		24—34	6.0	"	traces	0.468	2.47	2.72
Same	3	0—20	Not det.	"	"	0.497	7.04	8.34
		25—35	"	"	"	traces	3.48	2.69
Drogobych Oblast'. Forest	4	3—10	6.0	"	"	0.600	7.22	17.02
		15—25	4.5	"	none	traces	4.30	4.85
Drogobych Oblast'. Plowed land.	5	0—15	9.0	"	traces	1.52	4.03	4.49
		19—29	6.0	"	"	traces	4.47	4.87
Drogobych Oblast'. Plowed virgin land.	10	0—15	Not det.	128.24	1.840	2.89	8.52	13.61
		25—35	"	111—58	0.597	traces	4.74	5.64
		40—50	"	Not det.	0.715	"	—	—
Drogobych Oblast'. New growth on cut-over area.	11	3—15	"	213.31	traces	0.620	11.65	14.93
		30—40	"	172.76	none	none	12.16	11.71
		42—52	"	Not det.	traces	"	11.21	11.62
Drogobych Oblast'. Forest	12	2—12	"	178.36	"	0.648	13.12	23.77
		15—25	"	110.18	"	none	6.06	4.99
		32—42	"	79.52	"	"	4.59	3.00
Drogobych Oblast'. Plowed land.	13	0—12	"	122.64	0.575	8.41	5.62	5.04
		25—35	"	105.98	0.368	0.606	4.43	4.55
		40—50	"	94.78	traces	traces	7.29	4.77
Chernovskaya Oblast'. Abandoned land.	14	0—10	"	Not det.	"	10.08	6.41	10.88
		13—23	"	"	0.574	0.333	2.34	5.79
		23—33	"	"	traces	traces	3.85	2.97
Stanislav Oblast'. Plowed land.	15	0—10	"	"	0.439	14.50	2.29	3.01
		17—27	"	"	0.458	12.87	2.06	2.89
		28—38	"	"	0.315	traces	1.81	2.23
		42—52	"	"	0.420	0.369	4.64	3.18
Same	16	0—10	"	"	0.541	25.72	4.49	1.38
		22—32	"	"	traces	0.469	1.84	3.81
		33—43	"	"	0.362	none	1.76	2.08
Stanislav Oblast'. New growth on cut-over area.	17	0— 7	"	"	traces	0.451	4.25	10.66
		15—25	"	"	none	traces	5.16	5.80
		30—40	"	"	"	none	1.72	2.62

gives very good results in fine-textured soils.

It is necessary to drain these soils when they are excessively wet. Drainage with clay tiles is the best method, ensuring an increase in yields of 25%-40% for grain and 40%-60% for potatoes. In order to make mole drainage effective, it is necessary to establish the mole in the upper part of the illuvial horizon on an even, gentle slope and to reinforce the outlets with clay tile.

When working the soil it is essential to take the climatic peculiarities into consideration, particularly excessive wetness. As previously stated, ridge plowing with ridges of 3-3.5 m wide, which corresponded with the sizes of horse-drawn implements, was widespread in the Pre-Carpathian Region in the past. The introduction of mechanization meant the beginning of ordinary plowing which had an unfavorable effect on the yields of agricultural crops. Therefore the question has arisen now of plowing in strips 7-8 m wide (corresponding to tractor-drawn machinery). According to figures from the Drogobych Experiment Field, the yield of winter wheat is 14.8 cntr/ha with ordinary plowing and 16.4 cntr/ha with plowing in narrow strips. Planting potatoes in strips produced yields which were 35.3 cntr/ha greater than those obtained with ordinary planting in 1949 and 46.3 cntr/ha greater in 1950.

In connection with the problem of combatting excessive wetness, it is essential to review the question of fall plowing which makes it possible to accumulate moisture. The experience of the local population indicates that when the land is plowed in the spring it is weathered and warmed more rapidly, the young shoots appear earlier, and the harvests are more stable. Therefore, it is necessary to test spring plowing and use it to replace fall plowing. Fall plowing should be retained where there are many weeds, but the land should be plowed again in the spring or stirred, particularly under potatoes or other cultivated crops. Spring working of the soil on the 1 May kolkhoz increased the sugar beet yield by 22.9% over the 195 cntr/ha yield obtained with ordinary working.

The depth of the plowed horizon is of great importance in the sod-podzolic soils of the Pre-Carpathian Region, and in sod-podzolic soils in general. Even in the first year deepening the plowed layer from 18-22 cm together with the application of manure and 2.5 metric tons of limestone/ha increased the potato yield from 267.2-285.4 cntr/ha and spring wheat from 13.6-16.3 cntr/ha in the Drogobych Experimental Field. Deepening the plowed layer should be done carefully in order to avoid bringing an unfertile eluvial horizon to the surface. The plowed horizon must be deepened and cultivated gradually in steps of 2-3 cm per plowing by plows with soil deepeners; manure and limestone should be applied at the same time.

Conclusions

1. The flat watershed areas of the northern foothills of the Carpathians are covered with unique soils which differ from the brown forest soils and the podzol soils of the South Pre-Carpathian Region (Transcarpathian Region).

2. The history of the development of these soils, the morphological structure of the profile, and the data from particle size analysis indicate a podzolic process of soil formation in these soils. A somewhat higher humus content with a depth of more than 10 cm for the humus-containing horizon provide a basis for classifying them as sod-podzolic types. The presence of bean-like particles of ferromanganese formed only when there is periodic excessive wetness, and also the dark blue and ocherous spots and strips indicate that the soils are waterlogged (caused by precipitation under the conditions prevailing in the North Pre-Carpathian Region). Consequently, the soils of the northern Pre-Carpathian Region should be classed as sod-podzolic superficially gleyed soils.

3. The sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region differ from the podzolic gleyed soils of the northern regions of the USSR which resemble them in their properties by a somewhat different morphological structure and a higher content of organic residues. This is explained by the fact that decomposition proceeds very slowly in the North under conditions of a cold climate, a well-developed moss cover, and constant excessive wetness. In the Pre-Carpathian Region, on the other hand, with its conditions of a warm, mild climate, a very weak development of the moss cover under deciduous trees, and alternation of the anaerobic process with the aerobic, there is complete decomposition of the organic residues and peat layers are not formed.

4. The sod-podzolic superficially gleyed soils of the Northern Pre-Carpathian Region of the Ukrainian SSR have little fertility. They are structureless and have a high hydrolytic and exchangeable acidity along with a considerable amount of available aluminum. The amount of adsorbed bases and the degree of base saturation are extremely low in these soils. The soils have little biological activity, nitrification processes are very weakly developed, and they contain very little available forms of phosphorus. After many years of human economic activity, the plowed lands have acquired more favorable properties than the forest soils, but the majority of the soils still remain little cultivated.

5. The unique soil and climatic conditions of the North Pre-Carpathian Region of the Ukrainian SSR require the application of specific measures to improve the fertility of the sod-podzolic superficially gleyed soils, namely: drainage, plowing in narrow strips, the replacement of fall plowing by spring plowing as much as possible, liming, the application of organic and mineral fertilizers, et cetera.

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INCREASING SOIL MOISTURE BY THAW WATERS UNDER CONTINENTAL CLIMATE CONDITIONS IN THE OB' FOREST STEPPE OF ALTAY KRAY[1]

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Damage caused by run-off of thaw waters is enormous and generally known. Every year thaw and rain waters carry away 10-12 metric tons and more of soil from a single hectare of cultivated land (with a gradient of 2-4°). The mineral elements contained in this soil are sufficient to produce large harvests. Growing gulleys render enormous areas with fertile soils useless (9, 12). It is well known that under the conditions of a continental climate, heavy run-off during the spring accounts for 60%-98% of the total for the year (3). The more severe the winter and the greater the depth of soil freezing, the greater the run-off of thaw waters (4). In addition to the foregoing consequences, the run-off of thaw waters gives rise to still other phenomena which do no less damage to agriculture than erosion. It increases the water deficit in the soil in general and decreases the amount of water which takes part in continental moisture circulation, particularly in the spring. The run-off of thaw waters also contributes to more frequent and more severe droughts (2, 4, 8, 10, 11).

In 1954 we conducted field studies with the object of developing methods for preventing run-off of thaw waters and erosion which would be applicable to the soil and climatic conditions of the Ob' Forest Steppe of Altay Kray. The period of snow melt is characterized by a general positive heat balance in the system which includes the atmosphere, the snow cover, and the soil. Its beginning coincides with the time that relatively stable zero or low positive maximum air temperatures occur. Under prevailing conditions in the Ob' Forest Steppe, the period of snow melt very frequently begins in the first or the second ten-day period in March. At this time the average daily temperature varies from 1.1-8.4°C, and the mean temperature taken over 7 years (1951-1957) was 4.3°C.

It is necessary to note that the freezing and thawing soil processes and the intake of thaw waters are studied little despite their enormous economic significance. There are almost no methodological instructions covering their study during the spring. The most complicated problems for us were: establishing the areas and shapes of the experimental plots, the number of replicates, and their distribution.

Since the basic cause for run-off of thaw waters was the frozen condition of the wet soil, the greatest attention was devoted to the study of its thawing. It is known that the coefficient of run-off is directly proportional to the depth of frost in the ground and inversely proportional to the thickness of the thawing surface layer. Goriugin established that there was a sharp decrease in the coefficient of run-off (actually a stoppage) when the ground was thawed down to a depth of 14-15 cm. We studied ground thawing in plots with a width of 4 m and a length of 20 m, with three replications. They were separated from each other by snowbanks. The width of the snowbank bases was 2 m. Kachinskiy (5) conducted his field experiments in a similar manner in his day. The depth of thaw in each plot was measured 10 times with a metal probe (diameter 0.5 cm). The change in soil moisture was observed in experimental and control sections with the object of obtaining data on dynamics of the water regime and the effectiveness of the intake of thaw waters. Soil moisture was determined by 10 cm depths, replicated 3 times.

The experiments were conducted at the Barnaul Fruit and Berry Station, which is located on level area with a general slope to the Barnaulka River (to the south). The size of the experimental and control sections was 400 square meters. The gradient of the surface was 1.0-1.5°. The plots were plowed in the fall (crops were planted in the spring when the experiments were completed). The plots were located on a flat, slightly apparent microelevation with a total area of about 1000 m^2. One side of the experimental plot adjoined the control plot. The plots were surrounded on all sides by a protective strip about 2 m wide, thus the possibility of an influx of thaw waters from outside.

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[1] Presented before the First Delegates' Congress of Soil Scientists, May, 1958.

Data on the temperature and frost depth were obtained from the Barnaul Agricultural Meteorological Station. In 1956, the ground was frozen to a depth of 150 cm by January 16 (according to the frost meter). The frozen layer became deeper later. In 1957, the ground was frozen to a depth of 212 cm by March 31. The average depth of the snow cover on the plots prior to thawing varied from 40-50 cm.

Spring, 1956. The soil is a dark gray podzolized sandy loam with an underlying layer of silty clay loam at a depth of 100-110 cm. The dynamics of the moisture were studied in the meter layer in 1956. Snow melting began on March 9. The first stage of the snow-melting period lasted from March 9 to March 28. It was characterized by the fact that heat in the atmosphere was spent chiefly in warming the snow cover. The average air temperature increased to 0°C. Water was found mainly in the solid phase. By the end of this stage the thaw waters had reached the ground surface. The second stage of the thaw lasted from March 28 to April 7-8. It was characterized by the following features: atmospheric heat was spent on changing the snow into thaw water, the mean temperature of the snow cover was relatively stable (equal or close to zero), and the amount of snow decreased gradually.

The run-off started March 31 and was essentially completed on April 5. Preparatory work was completed on March 13-14. The experimental and control plots were laid out, the amounts of water in the snow cover were determined (in the first plots they amounted to 120 mm and in the second to 112 mm), the snow cover was prepared — snowbanks were put up (with a width of 2 m at the base), and strips were prepared with exposed ground — the experimental plots with a width of 4 m. The snowbanks and strips were 20 m long. Three holes each were sunk in the control and experimental plots and soil moisture samples were taken. As a result of the preparatory work on the snow cover, the active surface of the experimental plot consisted of the snow surface (snowbanks) — 8400 m^2 and the ground surface — 6600 m^2. The active surface of the control plot, which consisted of snow, amounted to 10,000 m^2. Atmospheric precipitation amounted to 7.3 mm during the experiments. The observational data obtained during the ground thaw are presented in Figure 1.

Figure 1 shows the sharply different character of soil thawing in the experimental and control plots. By the time run-off started on March 31, the ground had thawed to an average depth of 23.3 cm in the experimental plots (strips); in the control plot, on the other hand, the snow lay on an icy crust covering the ground which began to thaw only after the snow and icy crust had disappeared and the run-off of thaw water had ended. By the time the snow had completely disappeared on April 7, the depth of ground thaw was 63 cm in the case of the experimental plots (strips) and 31 cm in the control; by April 15 the depths were 98.0 and 58.2 cm respectively. Thawing under the snowbanks began on April 8 and by April 15 there were half-thawed layers at depths averaging 30-80 cm. By April 30 the ground had thawed to the same average depth of 100 cm in both experimental and control plots.

The character of the soil thawing affected movement of thaw waters. Although most of this water flowed away in the control plots, the larger portion soaked into the ground in the experimental plot. This is clearly shown in Figures 2a and 2b.

The curves in Figure 2a for April 7 and 15 show the soil moisture in the strips with exposed surface (the experimental plots); those for March 14 and April 30 show soil moisture for the entire plot. From March 14 to April 15 soil moisture in the experimental plot increased from 103.49%-210.14% in the one-meter layer in the strips with exposed ground and increased up to 134.53% in the strips covered by the snowbanks. After making the necessary calculations, we found that the general water supply in soil of the experimental plot had increased up to 184.43% by April 15 and the increment amounted to 80.94%. By April 30 the depth of ground thaw had become the same for the whole section (the semi-thawed layers had disappeared) and averaged 103 cm. The general water supply in the soil was 162.76%, i. e. it had decreased by 21.67%.

Figure 2b shows the dynamics of soil moisture in the control section. From March 14 to April 15 the total water supply in the soil increased from 103.34%-115.73%. By April 30 the amount of water in the soil had continued to increase and reached 140-70%. We account for the changes in moisture from April 15-30 in the experimental and control plots by its redistribution in the soil. In this interval there was a loss of water in the experimental plot amounting to 21.67% and, on the other hand, a gain in the amount of water in the control plot of 24.97%.

Observations of changes in moisture along the soil profile and the depth of soil thaw confirm a clear-cut connection between them — the lower boundary of penetration of thaw waters coincides on the average with the depth of thawing. Data on the dynamics of soil moisture permitted the compilation of a summary diagram on the effectiveness of intake of thaw waters (in m^3/ha) by April 15 (Fig. 3a).

Of the total supply of 1273 m^3/ha of water in

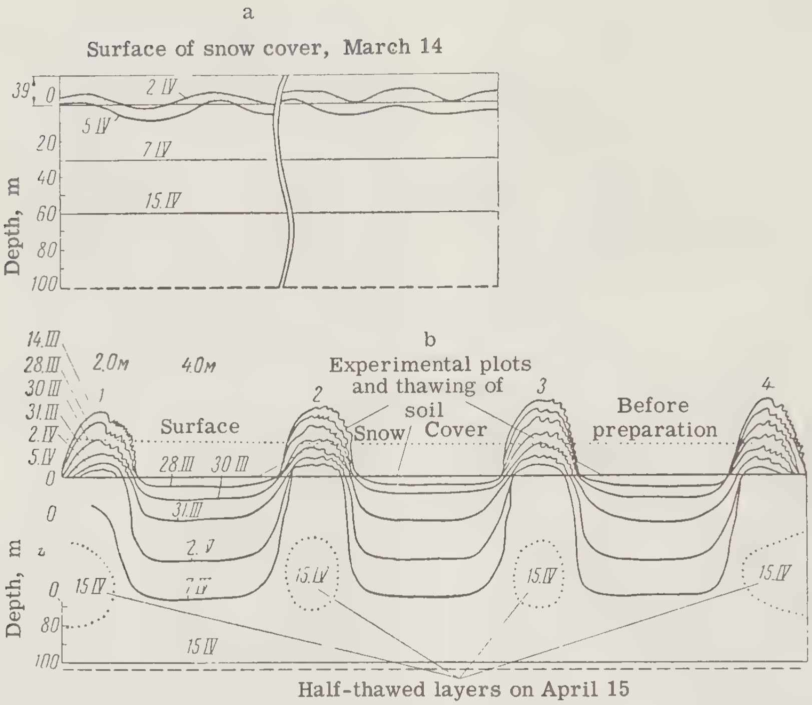

Fig. 1. - Diagram of the snow and ground thawing process in control and experimental plots during the period from March 14 to April 15, 1956.

a - control plot; b - experimental plot; 1, 2, 3, 4, - snowbanks and their thawing.

the form of snow and precipitation, which fell on the experimental plot during the experiment, 809.4 m³/ha entered into the ground. The losses (evaporation, possible partial run-off, etc.) amounted to 463.6 m³/ha. A sharply different picture was observed in the control plot: of the total of 1193 m³/ha of water only 123.9 m³/ha entered the ground; the losses amounted to 1069.1 m³/ha; the difference amounted to about 700 m³/ha.

Spring, 1957. The soil was a leached, medium-clay loam chernozem with a medium amount of humus. The dynamics of soil moisture were studied in the 1.5 m layer. The snow began to melt on March 18. The first stage of snow melting lasted from March 18-31 and the second stage from April 1-19. Run-off of thaw waters began on April 10 and ended essentially on the 14th. The snow cover left on April 19. An icy crust covering 60%-70% of the plot was formed from April 1-7. All preparatory work was done from March 21-23 and initial data were obtained. The snow cover was handled as it had been on March 22-23, 1956. The thawing depths in the open strips (experimental plots) are shown up to April 25 and for the entire experimental plot on April 25 (Table 1).

These data show clearly the difference in the soil thawing. By the beginning of the run-off of the thaw waters (April 10), the soil in the experimental plot (the exposed strips) had thawed to an average depth of 32.9 cm and only 1.0-5.0 cm in the control plot. The depth of ground thaw in the experimental plot as of April 25 was about the same over the entire area. On the same day samples were taken to determine soil moisture.

On the basis of data on the initial and final soil moisture, we constructed graphs (Fig. 2c and 2d) which show its changes in the experimental and control plots.

In the experimental plot (Fig. 2c) the total water content increased by 106.21% in the period from March 22 to April 25. In the control plot (Fig. 2d), the total water content in the soil increased by 64.28% in that time. It is necessary to note that the soil contained a larger amount of water before thawing in 1957 than it did in 1956, and its distribution along the profile was very irregular. The difference in the total water content in the control and the experimental plots was more marked, but in the upper (0-30 cm) and underlying layers, on the contrary, there was less difference between

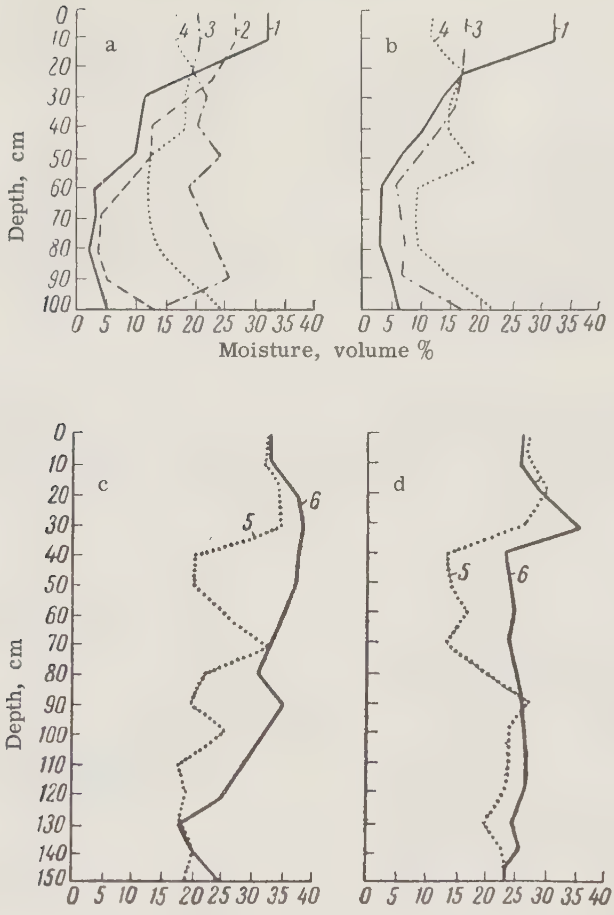

Fig. 2. - Changes in soil moisture in the experimental section.

a - exposed strips; b - control plot; c - exposed strips; d - control plot, 1, 2, 3, 4 - correspond to the dates March 14, April 7, April 15, and April 30 in the figures a and b. 5, 6 - correspond to the initial (period of snow thawing, March 22) and the final (after disappearance of the snow, April 25) soil moisture in figures c and d.

the control and experimental plots. This was connected with the soil texture and with the fact that far more rain had fallen in October of 1956, before freezing, (41.6 mm) than during the same period in 1955 (7.9 mm).

A diagram of the effectiveness of thaw water intake (m^3/ha; Fig. 3b) was constructed on the basis of data on changes in the soil moisture. In the experimental plot the soil absorbed 1062.1 m^3/ha of the total amount of water, amounting to 1295 m^3 of water/ha, in the form of snow and precipitation which fell during the experiment. The total losses were equal to 232.9 m^3/ha. In the control plot 642.8 m^3 of water/ha were taken into the ground out of a total 1220, and the total losses amounted to 577.2 m^3/ha. Thus, the total water increase in the experimental plot was more than 400 m^3/ha over the increase in the control plot. It is necessary to note that a larger amount of precipitation was taken into the ground in 1957 than in 1956, but the effectiveness of the intake was more pronounced in 1956. We understand the term effectiveness of intake to mean the ratio of the quantities of water absorbed into the experimental and control plots. In 1956 this ratio was 809.4:123.9 = 6.5; in 1957 it was 1062.1:642.8 = 1.6. Such a sharp difference in the results obtained in these two years

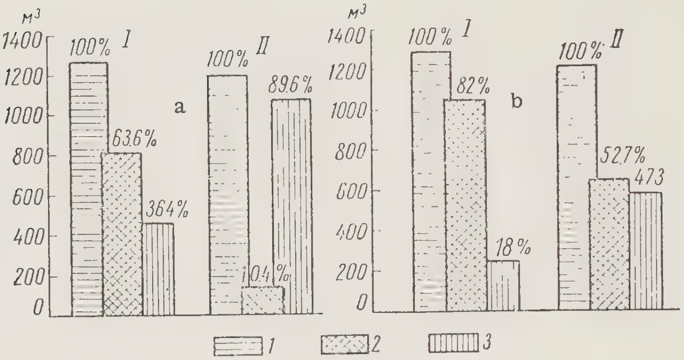

Fig. 3. - Effectiveness of thaw water intake and precipitation into the soil during the period of snow melting from (a) March 14 through April 15, 1956; and (b) from March 22 through April 25, 1957, m^3/ha.

I - experimental plot; II - control plot. 1 - total water content; 2 - intake into soil; 3 - total losses.

Table 1

Average data on the depth of soil thawing (cm) taken from observations

Plot	Observation dates					
	March 22	April 1	April 10	April 15	April 20	April 25
Experimental	0.0	23.0	32.9	47.7	66.2	120.0
Control	0.0	0.0	1.0—5.0	26.4	46.2	80.0

Table 2

Temperature conditions during the thawing of snow in 1956 and 1957

Index	Years		
	1956	1957	Difference
Total negative temperatures	—212.1	—101.9	—110.2
No. of days with average daily negative temperature	24	23	1
Average daily temperature on cold days of the period	—8.8	—4.4	—4.4
Duration of snow thawing, days	31	33	2

was caused chiefly by the different physical properties of the soils in connection with their peculiar temperature conditions in the cold period, particularly during the snow thaw. The total of the average daily temperatures below zero during the cold period was 2139.4°C in 1955-1956 and 1982.4°C in 1956-1957. The duration of the first was 158 days and the second, 148 days. The cold period of 1955-1956 was more severe and prolonged. The 1956 thawing period was distinguished by total negative temperatures twice those of 1957 and its average daily temperature was three times as low (Table 2). At the end of the period there was a sharp transition from negative temperatures to positive temperatures, which caused the rapid formation and run-off of thaw waters. The thawing period of 1957 was colder and the temperatures increased quite smoothly with time.

Thus, the method for increasing soil moisture yielded positive results under sharply different temperature conditions during the cold period and the snow-melting period and in different soils with different autumn precipitation.

Conclusions

1. The suggested method for increasing soil moisture sharply reduces the run-off of thaw waters and intensifies their absorption into the soil.

2. With the approach of the period of snow melt and with an average snow cover thickness of 40-50 cm, it is necessary to build up snowbanks 2 m wide and to clear 4 m exposed soil strips. This work can be done with a tractor fitted with a metal snowplow.

3. This method permits increasing the water content in the soil during the spring from 400-700 m^3/ha by sharply reducing the run-off of thaw waters.

4. In spite of a number of shortcomings in the experimental part of the work, the results obtained permit one to recommend this method for testing in agricultural production after taking local soil and climatic conditions into account.

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DETERMINATION OF IRRIGATION INTERVALS FROM THE MOISTURE OF A SINGLE SOIL HORIZON[1]

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Irrigation intervals in farming are mainly determined by schedules set up for the various soil-climate districts. Such patterns, however, do not always secure the best water regime for crop growth under the specific conditions of a particular farm because they do not make full allowance for differences in hydrological conditions on individual irrigated tracts. The failure of the irrigation scheduled to provide the best irrigation regime is especially evident in the new irrigated farming areas of the southern RSFSR and the Ukraine, where rainfall is sporadic during the growing season and most unevenly distributed. Such conditions require that the timetables be adapted to the specific soil-hydrological and weather situation. A number of scientific studies bear witness to the positive results obtained by adjusting irrigation intervals to fit the water needs of the plants (2).

One of the most thoroughly studied and reliable indicators of adequate water supply to crops by irrigation is the soil moisture status. Numerous investigations have established that the maintenance of soil moisture between irrigations at 65%-70% of the field moisture capacity (FMC) provides a most favorable water regime for plant growth. For moisture-loving crops and in saline soils, moisture between irrigations must not drop below 75%-80% of the FMC, while in some types of soil it can go to 60%-55% without significant harm to the yields (1). These guidelines to a greater or lesser extent have been established to fit the soil-climate needs of the basic biological groups of agricultural crops and are being defined more accurately by scientific-research institutions at the present time.

Determination of irrigation intervals by the average soil moisture of a significant layer is very laborious. This hinders its use not only in farming, but even in scientific research institutions conducting agricultural experiments under irrigated conditions. Yet this tedious, but at the same time reliable, method of determining irrigation intervals can be simplified considerably. We showed this to be possible for cotton, and Kabayev showed that it is feasible in Central Asia (3). In examining numerous data on soil moisture which was made available by the Brilevskaya Scientific Research Irrigation Station (Tsjurupinsk district, Kherson region), we discovered that in soils of uniform texture and identical hydrophysical characteristics to a depth of 1 m, the soil moisture at a depth of 30 or 40 cm practically coincides with the average moisture of the significant zone. Typical examples of soil-moisture determinations to a depth of 1 m under some irrigated agricultural crops are shown in Table 1.

The data of Table 1 show the comparatively even moisture distribution in the first meter of soil planted with these crops, although they belong biologically to different species with their own distinct peculiarities of growth and development, water requirements, etc. The soil moisture at the depths indicated in Table 1 was close to average for both the first meter and the first half-meter of soil. The upper 20-cm layer is an exception; this in some instances was drier than other horizons.

We made a statistical analysis of extensive data on the soil moisture under certain agricultural crops provided by the Brilevskaya Scientific Research Irrigation Station. Moisture data were analyzed for soils under corn, first- and second-year grass mixtures, sugar beets, and potatoes. Soil moisture prior to irrigation was at 50%-70% of field moisture capacity, depending on the experimental treatment. The root crops were irrigated from medium-depth non-flooded furrows, and the grass mixtures, from strips and

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[1] Work completed at the Ukrainian Scientific Research Institute of Irrigated Farming, Kherson.

Table 1

Typical examples of vertical moisture distribution in the first meter of soil under certain agricultural crops in 1956

Depth, cm	Corn Aug. 16	Mixed grasses		Sugar beets Aug. 20	Potatoes (spring-planting) Aug. 2
		1st year Aug. 24	2nd year Aug. 14		
10	12.7	12.9	8.3	11.9	11.6
20	12.3	13.6	8.4	13.0	12.5
30	11.8	13.9	10.7	14.2	14.3
40	12.3	14.7	10.9	14.4	14.2
50	12.2	14.5	11.1	14.4	14.1
60	12.4	13.5	11.3	13.7	14.2
70	12.9	13.6	11.2	13.5	14.5
80	13.8	13.0	11.2	13.0	13.9
90	13.6	12.0	10.8	13.1	13.5
100	13.2	11.9	10.8	12.8	13.0
0—100	12.7	13.4	10.4	13.4	13.6
0—50	12.3	13.9	9.9	13.6	13.3

furrows. Years during which the experiments were conducted (1955-1956) were moist (abundant rains, which wetted the soil 30-40 cm, often alternated with small rains, which penetrated only the 5-10 cm; 1953 was moderately moist, and 1954, dry. Thus the statistical analysis encompassed data on soil-moisture dynamics for years of varying precipitations, for irregular rains during the growing season, and also for different types of crop irrigation. The agricultural productivity level of the experiments was high. Depending on the particular experimental conditions, the corn yield was 40-44 cntr/ha; the mixed-grass hay (alfalfa and grain) amounted to 100-112 cntr/ha; the sugar-beet yield was 400-500 cntr/ha; and the potato crop 200-270 cntr/ha.

The soils of the experimental tracts are dark-chestnut and chestnut, medium and slightly solonetzic, with silty, slightly clay-loam, and sandy loam. The field moisture capacity of the silty, slightly clay loam soil varied to a depth of 1 m from 20%-18% of the absolute dry weight; that of the sandy loam, from 17%-15%. The texture of the 1-m layer was also relatively uniform.

Soil moisture was determined systematically: either every ten days during the growing season or as proper timing if the irrigations required. The soil was sampled by 10 cm depths down to one meter, with six cores for each experimental treatment, at the ridge and bottom of the furrow. Samples 2-3 cm thick were taken from the lower portion of the cores at depths of 10, 20, 30 cm, etc. Mean values of the six samplings were used in the statistical analysis. The analysis included more than 38,000 moisture determinations.

Given in Table 2 are the coefficients of correlation for soil moisture at depths of 30 and 40 cm as compared with the mean moisture of the meter layer on the other. The coefficients of correlation did not, in the majority of cases, exceed +0.90, nor were they lower than +0.83. This high correlation indicates that, in the absolute majority of cases, an increase or decrease in soil moisture at 30 and 40 cm is accompanied by a corresponding increase or decrease of the mean moisture over the layer from 0-100 cm. Neither irrigation nor precipitation had any appreciable effect in this, as confirmed by the high coefficients of correlation for all the years and all the crops given in the table. This high correlation is also apparent if we compare moisture at these depths with the mean moisture of the 0-50 cm layer.

In Tables 3 and 4 are shown deviations of soil moisture at 30 and 40 cm from the mean moisture in the 0-100 and 0-50 cm layers. These figures indicate that, in the majority of cases (70%-80% or more), the difference between soil moisture at 30 and 40 cm, on the one hand, and the mean moisture in the 0-100 and 0-50 cm layers, on the other, does not exceed 1% of the absolute dry weight. Only for the grass mixtures and sugar beets were larger deviations, exceeding 1%, noted. This is explained by the shallow wetting of the soil after crop irrigation. With a large number of irrigations the dry soil between irrigations was moistened only to a depth of 35-45 cm, and moisture at the 30 and 40 cm depths was usually 1.5%-2% greater than the mean moisture of the meter layer. Typical cases of moisture distribution following moderate irrigation are shown in Table 5.

Table 2

Coefficient of correlation between soil moisture at 30 and 40 cm and in the 0-100 cm layer

Crop	Year	Number of given moisture data (n)	Coefficients of correlation	
			r: 30, 0-100	r: 40, 0-100
Corn without crop irrigation	1953	71	+0.95	+0.94
	1955	28	+1.00	+1.00
	1956	27	+0.98	+0.99
Corn with crop irrigation	1953	51	+0.95	+0.97
	1954	28	+0.97	+0.99
	1955	31	+0.83	+0.97
	1956	30	+0.94	+0.98
Grass mixture, 1st year	1954	49	+0.87	+0.92
	1955	37	+0.96	+1.00
	1956	17	+0.94	+0.95
Grass mixture, 2nd year	1953	57	+0.90	+0.95
	1956	27	+0.91	+0.94
Mixed annual grasses, (corn and Sudan grass)	1956	23	+0.89	+0.97
Sugar beet	1955	17	+1.00	+1.00
	1956	16	+0.92	+1.00
Potatoes	1953	18	+0.97	+0.90
	1955	29	+0.96	+0.97
	1956	35	+0.97	+0.97

Table 3

Deviation (in %) of soil moisture at 30 cm depth from average moisture in 0-100 and 0-50 cm layers

Crop	No. of determinations compared	Compared to the layer:							
		0—100 *см*				0—50 *см*			
		0—0.5[a]	0.6—1.0	1.1—1.5	>1.5	0—0.5	0.6—1.0	1.1—1.5	>1.5
Corn without crop irrigation	126	61	22	15	3	80	17	2	1
Corn with crop irrigation	140	58	26	13	3	79	17	4	0
Grass mixture, 1st year	103	43	33	15	9	59	30	6	5
Grass mixture, 2nd yr.	84	36	25	14	25	61	26	7	6
Sugar beet	33	40	33	15	12	58	30	9	3
Potatoes	47	60	17	17	6	70	16	9	5

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[a] Amount of moisture deviation in percent of absolute dry weight.

Table 4

Deviation (in %) of soil moisture at 40 cm depth from the mean moisture in the 0-100 and 0-50 cm layers

Crop	No. of determinations compared	Compared to the layer:							
		0—100 *см*				0—50 *см*			
		0——0.5	0.6——1.0	1.1——1.5	>1.5	0——1.5	0.6——1.0	1.1——1.5	>1.5
Corn without crop irrigation	126	61	28	9	2	40	39	12	9
Corn with crop irrigation	140	69	22	8	1	66	26	5	3
Grass mixture, 1st year	103	44	27	18	11	32	30	27	11
Grass mixture, 2nd year	84	49	26	14	11	32	33	19	16
Sugar beet	33	27	27	24	22	39	30	12	19
Potatoes	47	51	36	11	2	62	30	4	4

Table 5

Instances of greatest soil-moisture deviation at 30 and 40 cm from mean moisture in the 0-100 cm layer

Depth, cm	Corn August 11, 1953	Grass mixture		Sugar beets September 10, 1956	Potatoes (summer-planting) September 10, 1955
		1st year July 25, 1956	2nd year Aug. 25, 1956		
10	16.3	16.1	15.6	14.6	15.7
20	18.0	15.0	15.8	14.8	16.1
30	17.1	14.0	15.7	15.3	14.8
40	16.8	11.7	14.3	14.9	11.4
50	15.5	10.8	13.2	13.8	11.6
60	13.6	10.6	12.4	13.6	10.8
70	14.1	10.5	11.2	12.7	10.6
80	13.1	11.8	11.3	12.1	12.1
90	13.4	11.0	11.0	12.3	12.6
100	12.1	11.8	10.9	12.4	13.7
0—100	15.0	12.4	13.1	13.7	12.9
0—50	16.7	14.1	14.9	14.7	13.9
No. of days after irrigation	3	4	4	4	1

The data in Table 5 show how the condition of the significant soil layer is related to the amount of water available to plants. Apparently water content for plants is more accurately characterized by the mean moisture in the 0-50 cm layer, although the depth of the significant layer for the dates shown in Table 5 reached 80-100 cm. With the readily available moisture of the upper soil zone at their disposal, the plants did not experience a water deficit in the considerably dried out lower horizons of the root zone. In the ensuing period water was supplied predominantly from the high-moisture zone. When it was time for the next irrigation, the moisture over the meter layer had again evened out.

Calculations showed that the difference between moisture content at 30 and 40 cm and the mean moisture content of the significant layer does not exceed 1% of the absolute dry weight in the absolute majority of cases. That is to say, the difference does not exceed the error of moisture determination when the significant layer is determined with due regard for developmental phases, biological characteristics of crops, and instances of irregular soil wetting following moderate irrigation as noted previously. The deviation is also less when the mean moisture in the 30-40 cm layer is compared with the mean moisture of the significant layer.

Thus, in soils of uniform texture and the same hydrophysical characteristics throughout the 1-meter layer, moisture at 30 and 40 cm or in the 30-40 cm layer coincides in the absolute majority of cases with the mean moisture of the significant layer.. This principle holds for a number of crops grown under irrigation and is true over a wide moisture interval — from the field moisture capacity to the wilting percentage.

Consequently, irrigation intervals can be determined from the state of the soil moisture at 30 and 40 cm depths.

The accuracy of the proposed method for determining irrigation intervals is quite high, as is shown by the following calculations. The daily moisture supply for a group of crops during the period of greatest water demand is 60-70 m^3/ha, but this may reach 100-110 m^3/ha for cotton. At the same time, a change of moisture in a half-meter layer equal to 1% of the absolute dry weight (bulk density, 1.4) corresponds to a change in the moisture content of 70 m^3/ha, or the daily requirement. Thus the error in determining the time of the next irrigation does not exceed 1-2 days.

Marked regularity of moisture distribution across the significant layer is clearly evidenced in soils with a relatively uniform texture and nearly identical hydrophysical characteristics. Quantitative correspondence of moisture at 30 and 40 cm with the mean moisture of the significant layer is not to be expected in soils of other makeup.

At the present time we still do not have a device for determining soil moisture as convenient and reliable as the soil thermal probe. Meanwhile, in view of the proposed method of determining irrigation intervals from the soil moisture at 30 and 40 cm depth, the development of such a device and its issuance to kolkhozes and sovkhozes would solve adequately the problem of determining irrigation intervals for the operating farm.

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TOPOGRAPHY AND WATER REGIME OF THE SOIL

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Classics of Russian agronomy have given great importance to the influence of relief on the water regime of the soil. Vysotskiy (3) noted that relief creates quite different hydrological conditions over the very shortest distances, reducing moisture in some sections and increasing it in others. Vil'yams (2, p. 12), the initiator of the grass-field system of farming, wrote: "Obviously, moisture conditions will be different in every area: on a watershed they will be uneven, and in a valley moisture conditions will be constant. Watershed vegetation will at times suffer from insufficient water, and in a valley the entire soil is continuously supplied with water."

Similar statements can also be found in soil science textbooks. For this reason measures to improve the water regime of the soil are directed primarily to watershed plateaus and do not give due consideration to river valleys, since these are considered better-watered areas. The latter grow the more moisture-loving and valuable crops. But the opposite situation is also observed in nature, i.e. in river valleys there are areas which are drier than neighboring watersheds.

In the high Trans-Volga the floodplain terraces of rivers and the depressed lowlands are not wooded. Their steppe condition shows the influence of a geomorphological factor, the presence of a diluvial deposition, and a microclimate which is drier and more continental in the valley than on upland slopes (5).

In the Bashkir ASSR, southern influences move north in depressed areas, since a continental climate, diminished precipitation, and higher temperatures in summer are characteristic of this topographic element (4).

S. S. Neustruyev (1931, p. 28) noted the valley grasslands in the taiga zone of Siberia. He wrote: "The short Yakutian summer (in the Lena valley) with its twenty or more hours of sun daily affects the soil moisture in such a way that steppe grasses and solonetzes and solonchaks make their appearance there and grain and vegetable crops are no worse off than in more southern latitudes."

In the western Ukraine a large area of podzolized soils intrudes southward along the elevated portion of the Volyno-Podol'sk plateau. As the plateau drops, the strongly podzolized soils give way to weakly podzolized and leached chernozems. Associated with lower topography are typical chernozems, which are almost fully podzolized on the plain (7).

In the Tatar ASSR, on the right bank of the Sulitsa River, strongly podzolized soils occur on watershed plateaus, gray weakly podzolized soils on slopes, and leached soils in the river valley (6).

In the northern part of the Bashkir Priural'ye, podzolic soils together with gray forest soils and chernozems occupy the more elevated topography. In the Bashkir Priural'ye area on the right bank of the river, podzolized chernozems occur on elevated topography. They are replaced on slopes by chernozem soils that are less markedly podzolized. On the Zilairsk upland and the eastern slope of Ural-Tan, narrow zones of chernozem soils along river valleys are wedged into the forest zone with its podzolized soils (1). In the northern part of the Chermasan-Demsk steppe, narrow zones of carbonate chernozems run along river valleys. In the interfluves, residually podzolized dark-gray and gray forest soils occur on the upper slopes; and on the slopes, leached chernozems.

As we go south, forest soils are replaced on the interfluves by leached and typical chernozems. This soil distribution according to topography testifies to the fact that soil moisture is not always more abundant in river valleys, and watersheds and upper slopes do not always have an unfavorable water regime.

We undertook a study of soil moisture in various types of topography in the Chermasan-Demsk steppe of the Bashkir ASSR. This steppe is situated in the central part of the Bashkir Priural'ye. Its climate approximates that of the dry southeast European part of the Soviet Union. The mean annual precipitation, according to many years' data, is 369 mm.

Topographically the Chermasan-Demsk steppe consists of asymmetrical interfluves with short south and southwest slopes and long gentle north and northeast slopes. As a rule the former are convex; the latter, concave and straight. The watershed plateaus are flat areas dissected by a network of gullies and ravines.

The soil of the watershed plateaus and north slopes is a complex of typical and carbonate chernozems, with a preponderance of the former. Eastern slopes and talus of all exposures are occupied chiefly by carbonate chernozems. Profile 20 is most characteristic of the typical chernozems of the watershed plateaus and northern slopes.

Profile 20. Buzdyakskoye experimental field. Third field crop rotation, third field. Watershed plateau.

A_p	0-23 cm	Dark-gray, typical chernozem, finely granular; thickly penetrated by the roots of spring wheat, clay loam.
A_1	23-25 cm	Dark-gray, silty-finely granular; penetrated by roots, clay loam. Transition to next horizon weakly pronounced.
A_2	35-48 cm	Light gray, finely granular, clay loam. Transition to next horizon is gradual.
AB	48-60 cm	Light-gray, coarse granular, clay loam. Transition to next horizon is sharply pronounced.
B_1	60-80 cm	Reddish, blocky, clay loam, abundance of pseudomycelium. Transition to next horizon poorly defined.
B_2	80-100 cm	Reddish, large-blocky structure, clay loam, abundance of pseudomycelium.

Profile 14 is given to describe the carbonate chernozems of these same topographic situations.

Profile 14. Buzdyakskoye experimental field. Third field crop rotation, second field. Watershed plateau.

A_p	0-20 cm	Dark gray, small-blocky-silty, slightly powdery, friable; plowsole very poorly defined. Abundant rootlets. Slightly moist. Transition gradual.
A_1	20-40 cm	Dark gray, friable, silty-granular, unstable, slightly gravelly, slightly moist.
A_2	40-65 cm	Dark gray with light browning toward the bottom of the horizon, silty-granular-blocky, with poorly expressed structure, but coarser than in A; weak manifestation of pseudomycelium; moderate moisture.
B_1	65-86 cm	Dark brown, silty-granular-blocky, structure not clearly expressed, easily disintegrates; abundant pseudomycelium. Moist. Gravel.
B_2	86-98 cm	Yellowish dark brown, structureless, moist.
C	98-130 cm	Yellowish brown, structureless. Abundant pebbles and gravel, local accumulations of lime resulting from decomposition of calcareous pebbles; pseudomycelium as far as 108 cm, below less moist, coarse clay loam. Surface effervescense from 10% HCl.

Profile 13 is characteristic of the carbonate chernozems of eastern slopes.

Profile 13. Buzdyakskoye experimental field. Second field crop rotation, field No. 1. Slope with eastern exposure.

A_p	0-20 cm	Dark gray carbonate chernozem, silty-blocky structure; clay loam.
A_1	20-35 cm	Dark gray, finely-granular structure, mycelium of carbonates occurs in lower part of horizon; clay loam.
A_2	35-49 cm	Dark gray with weak brownish tinge, silty-granular structure, fine clay loam.
B_1	49-65 cm	Dark brown, coarse granular structure; abundance of pseudomycelium.
B_2	65-79 cm	Brown with reddish tinge, structureless, fine clay loam, compact; abundant pseudomycelium of carbonates.
C	79-120 cm	Reddish brown, structureless, fine clay loam; abundance of pseudomycelium of carbonates. Surface effervescence from 10% HCl. Strongly penetrated by earthburrows.

Somewhat different from these carbonates are the chernozems of the talus. These are characterized by a thicker humus horizon.

Profile 15. Buzdyakskoye experimental field. First field crop rotation No. 7. Talus of eastern slope. Carbonate chernozem.

A_p	0-22 cm	Dark-gray, silty-blocky structure, fine clay loam.
A_1	22-45 cm	Dark-gray, silty-granular

	unstable structure, fine clay loam.
A_2 45-80 cm	Dark gray with brown tinge, silty-granular structure, weakly defined, fine clay loam; pseudomycelium occurs in lower part of horizon.
B 80-95 cm	Dark brown, silty-blocky structure, fine clay loam; quite compacted.
C 95-150 cm	Reddish brown diluvial clay loam. Surface effervescence from 10% HCl.

Local relief has a real influence on microclimate. In the Chermasan-Demsk steppe on raised relief (watershed plateaus, upper slopes), daily maximum and minimum temperatures vary less sharply in the plow layer. On lower topographic elements (talus) there is characteristically a much wider variation between diurnal heating and morning cooling in the plow layer.[1]

Observations indicate that relative humidity on the watershed plateau in spring is higher than on the talus with eastern exposure (Table 1).

Table 1

Mean monthly atmospheric relative humidity (average for 1950-1952), %

Month	Watershed plateau	Talus of east slope
April	83	54
May	75	67
June	63	68
July	71.5	70
August	71	70
September	78.5	74
October	75	81

Winds blowing along the valley of the Chermasan river (south and southeast) are stronger on the talus than on the watershed plateau (Table 2).

An abrupt change in wind speed is observed, beginning on the upper third of the slope. This is explained by the fact that the valley of the Chermasan River is a corridor, considerably more restricted in cross-sectional area than the flat broad watersheds. Air masses descending into the Chermasan corridor (which runs in the same direction as the prevailing winds), where it is narrow, increase the wind speed. In addition to this, winds are stronger in the Chermasan River valley because of inversion of the air masses. Warm air masses rise because they are lighter, and their place is taken by descending currents of cold air from the Belebey plateau. A local wind springs up along the river valley. The confluence of local winds with the south and southeast winds prevailing here results in stronger winds and produces "black storms" and snowstorms. Snow is deposited unevenly on different topographic elements.

As is shown from the data in Table 3, at the start of winter the difference in snow depths on different topographic elements is significant. The distribution of the first snow in large measure shows the effect of vegetation and tillage operations. But when the thaws arrive, snow depth on the talus is less than on the watershed plateau.

There is a difference also in the depth of the ground water in different topographic elements.

We see from Table 4 that the ground water in watershed plateaus lies closer to the surface than in the talus. This location of the ground water is obviously due to impermeable horizons.

Soil moisture was observed on slopes, on the taluses facing east and north, and on watershed plateaus. Special areas of carbonate chernozems were selected for this. Agricultural use during the period of observation was the same for all topographic elements — spring wheat after rye.

Measurements were made on an eastern slope in a forest belt running from a water divide down along the slope. Soil-moisture determinations were replicated three times. The mean values are given in Table 5. On the periphery of the watershed plateau the reserve of unavailable moisture was 205 mm, but on the talus, 192 mm.

Over a period of six years the moisture content of the upper 120 cm of soil on the eastern slope at the edge of the watershed plateau was greater than on the talus. This fact can be explained by the following. The soil moisture content in the Chermasan-Demsk steppe is primarily the result of autumn-winter precipitation. Autumn rains wet the soil more or less evenly regardless of topography.

Additional soil moisture from meltwater is distributed unevenly according to topography. Except in 1951, the moisture reserve in 120 cm

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[1] For more on this see the paper by R.N. Lysak. 1959. "Influence of topography on the temperature of the plow layer of chernozem." Pochvovedeniye No. 12.

Table 2

Wind velocity at surface of Chermasan River valley east slope, in % of speed on the first flood plain terrace, 1954-1955

Elements of relief	Wind velocity over fall-plowed surface at heights of					
	100 см			15 см		
	In meters per second					
	6.4	8.3	13.2	4.3	6.2	10.4
Flood plain terrace	100.0	100.0	100.0	100.0	100.0	100.0
Talus of slope	99.4	88.5	86.5	98.2	86.4	83.1
Lower third	98.1	87.5	83.9	95.5	83.5	80.9
Midslope	96.1	86.4	81.0	90.2	81.7	78.8
Upper third of slope	91.2	50.5	45.4	84.3	47.7	42.3
Watershed plateau	92.1	45.9	42.1	85.6	41.8	38.9

Table 3

Depth of snow cover on various topographic features for fall plowing, cm (average for 1949-1954); slope of eastern exposure, incline 2.5°

Month	Watershed plateau	Slope	Talus of slope
December	11.9	10.8	6.8
January	14.8	13.3	10.5
February	21.0	20.5	15.4
March	22.3	18.6	12.3

layer on the talus did not increase significantly after melting below 60 cm on the talus, and in some years this wetting extended only to the depth of the plow layer. The soil at the periphery of the watershed plateau was usually wetted to depths of 120-130 cm. The difference in moisture content is the result of an unequal distribution of snow according to topography.

The data of Table 6 show that before snowmelting the depth of the snow cover and its water content were considerably higher on the periphery of the watershed plateau than on the talus. In addition to the effect of snow-cover depth on soil moisture, there is the effect of the type of melting. The snow on the talus is evaporated by the strong winds; i. e. it is "eaten away" by the winds and the soil receives an insignificant proportion of meltwater. Little moisture is added to soils on the talus by surface runoff from the slopes, since this concentrates in small depressions, forms rivulets, and does not run off as a continuous sheet over the entire surface. For this reason, therefore, soil moisture does not increase over the entire area of the lower slopes. Obviously there is no subsurface flow in the steppe. No subsurface flow was observed even in the early spring. The low relative humidity and also the winds adversely affect the water regime of the talus. This same situation was also observed on a slope of northern exposure (Table 7).

The water regime of the soil gets worse as we approach the river valley. Most favorable conditions are present on the watershed plateau. On the north slope, however, soil-moisture differences conditioned by topography are less pronounced as compared with the southern slope.

Similar data were obtained also from a survey trip over the Chermasan-Demsk steppe. Near Staraya Karmaly-Bash village the moisture content of 120-cm soil on a watershed plateau on August 5, 1952, was 36 mm higher than on the talus. In the Asly-Udryak River valley on June 26, 1953, the moisture content was 26.4 mm less than on the watershed plateau.

But as snow distribution, temperature regime, and the relative humidity change on the talus and other lower topographic features, the water regime of the ground also changes. As an example of this let us cite the results of observations on the water regime of soils in a forest belt on an eastern slope in the Buzdyakskoye experimental field.

The height of the forest belt is 5 m, the width is 18 m. It is made up of the following species: Rows I and II, acacia; III, ash-leaved maple; IV-V, poplar; VI, acacia; VII-VIII-IX, ash-leaved maple; and X, acacia. The forest belt was of the dense type.

From the data obtained (Table 8) we see that

Table 4

Depth of ground water, meters, according to borings on the Buzdyakskoye experimental field

Observation dates	Watershed	Talus	Observation dates	Watershed	Talus
1950			1950		
May 13	6.5	7.2	Sept. 15	6.5	7.0
June 14	6.3	8.0	Oct. 15	6.8	7.4
Aug. 14	6.3	8.2	Nov. 14	6.9	8.0
1951			1952		
Febr. 14	6.5	8.3	Jan. 18	6.6	8.5
Febr. 15	6.8	8.5	Febr. 13	6.5	8.2
March 21	6.9	8.7	March 14	6.7	8.2
April 1	7.0	8.9	April 17	6.5	7.8
April 10	6.3	7.3	May 14	6.5	8.0
May 14	6.6	7.8	June 17	6.5	8.3
June 12	6.4	7.8	July 15	6.1	8.2
July 13	6.8	8.0	Aug. 14	6.4	8.1
Aug. 15	6.5	8.1	Sept. 13	6.4	8.2
Sept. 14	6.4	8.2	Oct. 13	6.2	8.0
Oct. 5	—	8.2	Nov. 14	6.8	8.1
Nov. 14	6.4	8.2	Dec. 14	8.8	8.8

Table 5

Total moisture contents, mm, of 120 cm soil layer at various parts of eastern slope

Sampling date	At the periphery of watershed plateau	At talus	Sampling date	At the periphery of watershed plateau	At talus
Sept. 9, 1949	274	221	Aug. 20, 1952	244	234
Apr. 7, 1950	265	252	Sept. 3, 1952	198	163
May 11, 1950	287	233	Oct. 2, 1952	264	294
June 25, 1950	321	210	April 16, 1953	357	237
July 14, 1950	263	211	May 5, 1953	293	271
Aug. 17, 1950	246	195	June 5, 1953	333	246
Oct. 10, 1950	311	196	Nov. 4, 1953	353	302
Apr. 11, 1950	329	306	April 10, 1954	373	306
May 23, 1951	339	323	April 26, 1954	321	272
July 25, 1951	225	187	June 11, 1954	283	247
Sept. 20, 1951	181	171	Aug. 20, 1954	227	164
Oct. 18, 1951	238	184	Oct. 28, 1954	287	252
Mar. 31, 1952	281	190	Mar. 5, 1955	315	259
May 6, 1952	334	202	April 20, 1955	405	310
June 11, 1952	325	215	June 24, 1955	308	223

the water regime of a forest belt in an area of varying topography is quite different from that in the open steppe. Soil moisture increases as we go down the slope, and on the talus the moisture content of the soil is greatest during the whole observation period. In the spring after snow melting, soil moisture increases insignificantly on the talus in the open steppe, but under the forest belt it almost doubles.

Table 6

Depth of snow cover, cm, and melt-water content, mm, before snow melting

Topographic features	Years											
	1950		1951		1952		1953		1954		1955	
	Depth	Water	Depth	Water	Depth	Water	Depth	Water	Depth	Water	Depth	Water
Peripheral part of watershed	15.0	31.2	30.7	104	3.22	0.39	2.6	55	11	26.4	12.7	26.0
Talus of eastern slope	7.0	14.5	20.6	74.0	7.0	13.3	20.6	52	8	20.8	8.0	20.8

Table 7

Moisture content, mm, in 120 cm soil layer for various topographic features on a northern slope

Sampling date	On watershed plateau[a]	On slope[b]	Talus[c]	Sampling date	On watershed plateau[a]	On slope[b]	Talus[c]
Apr. 9, 1953	390	373	367	June 23, 1954	275	266	223
July 18, 1953	292	262	146	Nov. 10, 1954	284	279	220
Nov. 18, 1953	—	342	332	Apr. 30, 1955	375	274	180
May 14, 1954	327	367	304	July 4, 1955	225	203	145

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[a] Unavailable moisture content: 205 mm; [b] 221 mm; [c] 218 mm.

Table 8

Soil moisture content, mm in 120 cm soil layer for various topographic features of eastern exposure in a forest zone

Date	At the periphery of watershed plateau[a]	On slope[b]	On talus[c]	Date	At the periphery of watershed plateau[a]	On slope[b]	On talus[c]
May 11, 1950	332	364	460	May 7, 1952	348	314	441
June 25, 1950	285	290	325	July 15, 1952	277	244	283
July 14, 1950	256	305	302	Aug. 29, 1952	287	265	258
Aug. 17, 1950	242	295	292	Sept. 4, 1952	212	208	238
Oct. 10, 1950	344	342	370	Oct. 6, 1952	262	174	280
May 23, 1951	371	425	422	June 17, 1953	270	262	271
July 25, 1951	243	251	286	July 28, 1953	210	173	214
Oct. 10, 1951	244	269	283	Nov. 1, 1954	255	245	210

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[a] Unavailable moisture content: 205 mm; [b] 194 mm; [c] 192 mm.

The high soil moisture content on the talus under the forest belt is the result of the large quantity of snow accumulated in forest belts. Obviously, one of the sources supplementing the water regime of the soil on the talus under a forest belt running along the slope in the spring is the subsurface flow. The higher atmospheric relative humidity and reduced wind velocity in the forest belt reduce moisture losses by evaporative diffusion, so that the water regime of the soil under forest belts is more favorable than in the open steppe.

The observations show that soil moisture increase does not always follow local topography. In the Chermasan-Demsk steppe, more moisture is contained in a 120 cm layer of soil on the watershed plateau than in the river valley. The water regime in the soil cannot be completely dependent on surface and subsurface flow. A complex of factors affects it: snow cover, temperature regime, relative humidity of the air, wind velocity, and the physical properties of the soil. If the combination of these factors is favorable at higher elevations, then the soil may be more moist than in lower areas.

In laying out crops and planning the regulation of soil moisture we must not judge the soil water regime of any particular field on the basis of its elevation. We must take into account the entire complex of conditions affecting the accumulation and conservation of soil moisture.

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THE NATURE OF HUMIC SUBSTANCES IN THE BROWN MOUNTAIN-FOREST SOILS OF THE CRIMEA

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Brown mountain-forest soils in the Crimea form principally under the canopy of broadleaf forests. The humic composition of these soils depends on the chemical properties of the forest litter and the hydrothermal conditions of its decomposition.

V. V. Dokuchayev (2) first expressed the idea that the nature of humus corresponds to the type of soil formation. Vil'yams (1) showed that a definite type of humic acids is peculiar to a specific type of vegetation. Developing these ideas, Tyurin (4) established characteristic laws for the zonal soils of the USSR not only as regards the quantitative accumulation of humus, but also as to its qualitative composition. In base-unsaturated soils with low humic acid content, the major portion of these acids are free polymeric complexes thereof and also bound with free hydrates of sesquioxides. These as well as others are readily soluble when the soil is treated directly with 0.1 N alkali. These soils are characterized by the complete absence or low concentration of humic acids tied with calcium. Such humic acids predominate in the humus of chernozem and chestnut soils. The brown mountain-forest soils of the Crimea have not yet been studied in this respect.

We were faced with the task of finding out which fractions represent the humic acids in the humus of brown mountain-forest soils while determining the ash substances liberated in the decomposition of the leaf-fall and litter. Part of the ash reacting with the organic products of leaf-fall and litter decomposition form organomineral compounds specific for given conditions, and these define the nature of the humus of these soils.

The object of our investigations was the brown mountain-forest soils of the northern slope of the main Crimean mountain chain, which are developed on mid-Jurassic limestones, and soils which were developed on a mixed diluvium of mid-Jurassic argillaceous schists and sandstones. The district is characterized by a moderately warm climate. The mean annual precipitation is 631-761 mm.

The forest litter and leaf-fall gathered were sorted into two fractions. In the first fraction were put leaves, scales and fruit; in the second, brushwood, branches, wood and other components of litter and leaf-fall. The chemical composition of the ash of leaf litter and leaf-fall was studied according to the methods of Yermakov (3). Humic acids were extracted from the soil by Tyurin's method.

Results of Investigations

The chemical composition of the ash of fresh leaf-fall and litter is shown in Table 1. The different chemical composition of the litter ash is the result primarily of the nature of the soil-forming parent materials. Silica content is much larger in the litter ash of those forests growing on soils developed from carbonate materials. Oak and beech forest litter from brown mountain-forest soils developed on parent materials of different carbonate content in general is most saturated with calcium salts.

Litter ash composition consistently appears as follows: $CaO > SiO_2 > R_2O_3 > MgO$.

During decomposition the ash composition of the litter undergoes substantial changes. Depending on mobility, some of the ash substances are leached from the litter more quickly than the rest. The ash of a leaf litter is characterized by higher silica and sesquioxide contents than leaf-fall; in contrast, the calcium and magnesium salts in it are less than in leaf-fall.

The ash composition of the litter follows a different order: $SiO_2 > CaO > R_2O_3 > MgO$.

Calcium and magnesium compounds are leached out first during decomposition of the litter. Other ash substances leach out much more slowly, as is shown by the relative

Table 1

Chemical composition of leaf-fall and leaf-litter ash, % of ash

Forest	Material	SiO_2	R_2O_3	CaO	MgO
Oak on brown mountain-forest soil developed on mixed diluvium of agrillaceous schists and sandstones	Leaf-fall	34.80	10.33	35.14	5.31
	Litter	52.94	12.78	22.31	2.61
	Litter in % of leaf-fall	152.1	123.7	63.4	49.1
Oak on brown mountain-forest soil developed on diluvium of limestones	Leaf-fall	24.58	16.29	42.18	3.44
	Litter	50.10	13.29	28.83	1.58
	Litter in % of leaf-fall	203.8	81.5	68.3	45.9
Beech on brown mountain-forest soil developed on mixed diluvium of argillaceous schists and sandstones	Leaf-fall	36.36	12.20	29.62	4.50
	Litter	49.05	12.90	23.78	2.06
	Litter in % of leaf-fall	134.9	105.7	80.1	45.7
Beech on brown mountain-forest soil developed on diluvium of limestones	Leaf-fall	26.61	8.73	42.89	4.09
	Litter	48.35	13.05	24.54	1.35
	Litter in % of leaf-fall	181.7	149.4	52.2	33.0

Table 2

Fractional composition of humic acids extracted from soil before and after decalcification of humic acids, % of soil weight

Soil	Depth, cm	Humic acids		
		Total	Extracted directly with NaOH (free and bound) with mobile forms of R_2O_3	Extracted after decalcification (bound to Ca)
Brown mountain-forest on mixed diluvium of argillaceous schists and sandstones under oak forest	1—9	0.52	0.20	0.32
	9—32	0.23	0.15	0.08
Brown mountain-forest on diluvium of limestones under oak forest	1—10	0.96	0.12	0.84
	10—29	0.23	0.04	0.19
Brown mountain-forest on mixed diluvium of argillaceous schists and sandstones under beech forest	1.5—11	0.50	0.36	0.14
	11—27	0.07	0.03	0.04
Brown mountain-forest on diluvium of limestones under beech forest	1.5—6.5	0.42	0.19	0.23
	6.5—22	0.15	0.00	0.15

composition of the ash of leaf litter and leaf fall (Table 1). Calcium and magnesium, liberated from the litter, produce organomineral compounds with newly formed humic substances. Hydrates of sesquioxides are less available under these conditions. For this reason, apparently, their participation in humate formation is limited. The preponderance of calcium over other ash substances in leaf-fall, and also its high mobility, must lead to the predominant formation of calcium humates.

In Table 2 data are shown on the amount of humic acids extracted from the soil prior to decalcification (by direct treatment of the soil with 0.1 N NaOH) and after its decalcification. As is shown in the data, the calcium humates predominate in soils developed on limestones and also in certain horizons of soils developed on non-carbonate materials. The remaining is shown to be free of sesquioxide-bound humic acids. The presence of humic acids bound to sesquioxides can also be viewed as a result of the reaction of humic substances with the mineral portion of the soil, especially in the case of soils developed on non-carbonate materials.

Conclusions

1. Results of the investigation indicate a connection between the ash composition of leaf-fall, mobility of ash substances in the litter of oak and beech forests, and the fractional composition of humic acids in brown mountain-forest soils of the Crimea.

2. In the leaf-fall of broadleaf forests growing on soils developed from limestones, more calcium is present than in the leaf-fall of forests growing on soils arising from argillaceous schists and sandstones.

3. Saturation of the leaf-fall with respect to calcium, the high mobility of calcium and its reaction with organic products of leaf-fall decomposition lead to the preponderance of calcium humates in the composition of humic substances in the brown mountain-forest soils overlying limestones.

The calcium humate content in the humus of brown mountain forest soils developed on argillaceous schists and sandstones is relatively low.

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REVIEW

CULTIVATION OF SOILS AS A CONTEMPORARY STAGE IN SOIL FORMATION BY I.F. GARKUSHA

P. M. BALEV, Cultivation of Soils as a Contemporary Stage in Soil Formation

The book by I. F. Garkusha, published by the Belorussian Agricultural Academy in 1956, is devoted to one of the very real problems of contemporary agricultural soil science. For the first time a serious attempt has been made in this book to give a theoretical generalization of the enormous and varied material accumulated by scientific agronomy on the problem of improving the fertility of sod-podzolic and peat bog soils under the influence of the economic activities of man. In the foreword academician V. P. Bushinskiy gives a high evaluation to the scientific production significance of this work.

The book begins with a five page introduction in which the author elucidates some methodological propositions of the Marxist-Leninist teachings on soil fertility and the problems involved in improving it. The book is then divided into two parts.

The first part is devoted to an examination of the results obtained from studying the evolution of sod-podzolic soils under the influence of their cultivation. The second part sets forth the results from studying the evolution of peat bog soils under the influence of cultivation.

The first section (35 pages) of Part I is devoted to a survey of the scientific experimental works on the cultivation of sod-podzolic soils.

In the second section (74 pages) the author discusses the results obtained from studying the evolution of sod-podzolic soils of different regions of the forest-meadow zone under the influence of their cultivation.

The evolution of the peat bog soils was studied on the basis of the results noted in changes of the properties of peat bog soils under the influence of their cultivation on the Vedrich' Sovkhoz of Gomel' Oblast', at the Minsk Experiment Station, and at the Moscow Bog Experiment Station (53 pages).

General conclusions and an extensive bibliography (579 titles) are given at the end of the book.

Thus, a brief acquaintanceship with the contents of the book permits one to gain an idea of the problems in scientific production relations, that are discussed by the author in his expose of the experimental material and in his theoretical analysis and generalization.

In his literary survey of the cultivation of sod-podzolic soils, the author dwells on the first works on this problem which were classics of Russian agronomy (I. A. Stebut, A. V. Sovetov, V. G. Bazhanov, A. N. Engel'gardt, P. A. Kostychev, D. I. Mendeleev, and others). He discusses the works of the Soviet period more fully. The comments are quite detailed on the works by V. Ye. Yegorov, K. M. Smirnova, N. L. Blagovidov, P. M. Balev, and others in which the basic laws for improving the physiochemical properties of soils through complex methods for cultivating them are revealed.

A large amount of factual material, the results of thorough and many-sided studies by the author, is presented in the experimental part. This makes his conclusions thoroughly well-founded.

In the experimental studies of the evolution of sod-podzolic soils under cultivation, the changes in the following characteristics of the soils were studied: morphological features; total chemical composition; textural and chemical properties; structure; microflora; readily soluble P_2O_5 and potassium; and organic matter content broken down into basic groups.

Conclusions on the results obtained from research are given at the end of each section.

The studies on the evolution of peat bog soils were conducted in accordance with a narrower program which included studies of the changes in the morphological, chemical, and biological properties of peat bog soils under the influence of cultivation.

On the basis of his investigations Garkusha concludes that the sod-podzolic soils which occupy more than 50% of our nation's territory still do not possess high fertility. The author establishes that cultivation by man (working the land, fertilizer, plants) brings about a decrease or even accentuates the negative qualitative features of the podzol-forming process.

The basic factor in cultivating sod-podzolic soils — the complex application of organic and mineral fertilizers, liming, planting grass crops, and deep plowing — is properly emphasized in this book. Fertilizers constitute the central link in this complex.

The author presents a detailed and comprehensive discussion of the processes for improving the physicochemical and microbiological properties of the soil through cultivation: increasing the humus content; enrichment which food elements accessible to plants and organomineral colloids with adsorbed Ca and Mg; decreasing the free Al and Fe; improving the aggregate composition; etc.

The book correctly emphasizes that the time factor is of great importance, along with the proper application of complex agricultural measures, in solving the problems of improving the fertility of sod-podzolic soils.

Worthy of special attention is the author's conclusion that the purposeful improvement of soil fertility is possible only under the conditions of a planned socialist economy where there are unlimited possibilities for extensive application of all the progressive achievements of advanced scientific experience and the achievements of technology.

Familiarity with the experimental part of the work gives rise to the impression that at the present stage of soil formation in which the leading factor is the production activity of man, elements important to the life of people are being drawn into the biological cycle of substances in nature at an ever greater rate every year.

It seems to us that the production-genetic classification of cultivated soils of the sod-podzolic group, worked out by Garkusha, is of great scientific and production significance. The author has based this classification, not on morphological, but on production-genetic indices, which is an undoubted contribution to agronomical soil science.

However, in spite of the great value of this work by Garkusha, it does contain some shortcomings. An insufficiently critical approach toward certain experimental data and the propositions stemming from them is shown in the analysis of the literary sources on the problems under consideration. For example, on pages 40-41 (Table 36) the author presents data on the total composition of a sod-podzolic soil (by different agrotechnical backgrounds), from the agricultural experiment station of the Timiryazev Agricultural Academy, in which the amount of water-stable aggregates larger than 0.25 mm in diameter reach 70%-95% (?) in many treatments. Anybody knows that such an amount of water-stable aggregates might be wholly logical for such soils as a granular flood plain soil or a chernozem from a virgin steppe, but it simply cannot be characteristic of moraine coarse clay loam of Moscow Oblast'. Apparently these results were the consequence of violations of research methods since rock fragments, large quartz grains, feldspar, etc. were weighed in the pans along with the true aggregates after sieving in water.

It is not wholly clear as to why the author considered the question of "the importance of working the land in the cultivation of soils" separately from the question of "the importance of deep plowing in the cultivation of soils" (page 25).

On page 44 the author correctly points out that T. S. Mal'tsev emphasized the subject of the equivalence of perennial and annual plants in improving the structure of the soil and enriching it with humus. However, it is entirely incomprehensible why Garkusha, who had an enormous amount of experimental data at his disposal, did not consider it possible to point out the great qualitative and quantitative differences in the improvement of soil fertility by annual and perennial plants. The experimental data of recent years provide grounds for stating that if the process of enriching the soil by organic matter is brought about by the life activities of all plants (in part by lower soil organisms, too), then the role of perennial grasses is the most intensively displayed in this process. Moreover, the mechanical transfer of the conclusions from Mal'tsev's experiments to sod-podzolic and peat bog soils is not wholly justified.

Page 48 contains a reference from the work by V. Ye. Yegorov which indicates that deep plowing to 34 cm, which would mix the podzolic horizon with a part of the illuvial horizon, would ensure larger crop yields as compared with plowing to a depth of 16-18 cm. However, it would be well to point out still other data from the same author which indicates that deep plowing and bringing this horizon to the surface gives unfavorable results when the podzolic horizon has a high free aluminum content.

Data are given on page 53 on investigations of a reclamation method using three-layer plowing (V. P. Mosolov) without an adequate theoretical analysis. Research materials indicate that in soils where the illuvial horizon is a moraline coarse clay loam containing a significant amount of free aluminum, shifting this horizon to the place of the podzolic horizon (immediately under the plowed horizon) has an unfavorable effect on the growth and development of plants.

Consequently, every method (or combination of methods) for deepening and cultivating sod-podzolic soils must be considered by taking the specific conditions into account, not from general propositions.

It is impossible to agree with the author's statement that all the classifications of cultivated soils previously established did not reflect "the most important properties of the soil which should essentially constitute the basis of the production-genetic classification of cultivated soils and serve as the index of the degree to which they are cultivated." It is well known, for example, that in the classifications recommended by workers of the VIUAA (All-Union Institute of Fertilizers, Agricultural Soil Science, and Agricultural Engineering) the changes in the indices of cultivation were always considered in connection with that which was changed, that is, in connection with changes in the initial properties of the natural soil subjected to cultivation.

The author has reduced the problem of the classification of cultivated soils to separating soils of different texture and different soil-forming parent materials into merely three degrees of cultivation: cultivated, moderately cultivated, and slightly cultivated.

The types of soil cultivation can differ in connection with the varied character of the productive use of areas; thus the quantitative indices which reflect the degree of cultivation for different soils can also differ and deviate strongly at times from those which the author gives.

The author of the book criticizes the works on the degree of soil cultivation written by the VIUAA in 1933-1935. He points out that the separation of soils by their degree of cultivation was based essentially on the amount of manure applied to them, while the degree of cultivation is due to a complex of agricultural measures. However, he fails to consider that these works examine the problem of the cultivated — soil variations created by the landlord-peasant economy when manure was the chief factor for soil cultivation and when the amount of manure applied reflected the general level of agriculture on a given plot; there was a definite correlation with the entire complex of other agricultural methods applied to a given type of land use. When the cultivated soil variations created by socialist agriculture were classified, the VIUAA workers never suggested that classification should be restricted to only the amount of manure applied.

In 1940, N. P. Karpinskiy published the work "Series on fertilizer, agricultural engineering, and agricultural soil science," which contained a more detailed classification of plowed sod-podzolic soils in connection with their cultivation. Here the classification of cultivated soils was not based only on the amount of manure applied, but on a number of other processes occurring in plowed podzolic soils. Apparently the author does not know this work, which must be considered a serious omission.

In several places in Garkusha's work (pages 25, 108, 176), one encounters unclear statements to the effect that "when the soil is worked, the intensity of the podzol-forming process is decreased." When soils of the sod-podzolic type are worked, which have been plowland for a long time, there is no decrease in the intensity of podzolic formation, but a decrease or elimination of the unfavorable consequences of this process.

If we take into consideration the enormous areas of peat bog soils in the northwest and central regions of the non-chernozem zone which will be a reserve in the near future for expanding the sown areas, the elucidation of the basic laws of development of these soils when they are cultivated (contained in the second part of the book) will undoubtedly be of considerable value. In this connection it would be desirable to supplement this section with scientifically well-founded recommendations of methods for the effective cultivation of the basic types of peat bog soils.

On the whole, the book reviewed is of great scientific and production interest and constitutes a significant contribution to soil science. It is very desirable that this monograph be published with mass circulation.

CHRONICLE

THE EXPEDITION ORGANIZED BY SOIL SCIENTISTS OF THE LITHUANIAN SSR

THE EXPEDITION ORGANIZED BY SOIL SCIENTISTS OF THE LITHUANIAN SSR,
I. I. Vaytekunas

At the meeting of the board of the Society of Lithuanian Soil Scientists, which took place at the beginning of 1958, a decision was adopted to organize an expedition to the territories of the Lithuanian and Belorussian SSR and Kalingrad Oblast'. Representatives from the neighboring Latvian, Estonian, and Belorussian Republics, and from the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR were invited to participate in this expedition along with Lithuanian soil scientists. The objective of the expedition was to gain closer familiarity with the soils of the Lithuanian and neighboring republics and to clarify and coordinate opinions on certain classification problems in connection with the projects on evaluation of soil site quality.

The expedition took place August 18-28, 1958. Thirty persons took part in it: members of the Society of Soil Scientists from the Lithuanian Branch and guests from the union republics. The guests were: from the V. V. Dokuchayev Soil Institute, Ye. N. Ivanova and O. A. Vadkovskaya; members of the Society of Soil Scientists of the Latvian SSR, Tsirulis, Shults, and Frailand; and from the Belorussian SSR, P. P. Rogova. The Minister of Agriculture of the Lithuanian SSR, V. M. Vazalinskas, who participated personally in the work of the expedition, was of great assistance in organizing this expedition.

The problems to be solved and coordinated during the expedition were outlined at the meeting held on August 18:

1) Establishing the demarcation between the brown earths classified by Polish soil scientists and our podzolic soils;

2) Clarification of the problem of separation of the provinces of straw-yellow podzolic soils in the podzolic soil zone;

3) Improving the systematic list of soils adopted in 1952 for the Baltic republics;

4) The separation of the soil profiles formed on two-layer deposits into genetic horizons;

5) Agreement on methods for soil site-quality and a number of other problems.

The expedition followed a route of 1,500 km through southern and western Lithuanian SSR, Grodno Oblast' of the Belorussian SSR, and Kaliningrad Oblast', RSFSR. This route passed through Vil'nyus, Sal'chininkay, Lida, Grodno, Druskininkay, Alitus, Kaunas, Kapsukas, Chernyakhovsk, Kaliningrad, Sovetsk, Klaypeda, Nida, Klaypeda, Kaunas, Ukmerge and Vil'nyus. Nearly 50 soil profiles were examined.

The journey intersected the ancient moraine landscape; the fluvioglacial valley in Belorussia and in southeast Lithuania; the limnoglacial valley in southwest Lithuania and in Kaliningrad Oblast'; the massif of aerolian sandy areas of Kurshiy Nering; the hilly Zhemaytiyskaya Highlands; and the Baltic ridge region.

Coarse boulder clay loams frequently covered with sand or sandy loams on which medium sod and strongly podzolized soils predominated were characteristic of the ancient moraine landscape. The podzolic horizon (A_2) was given a preliminary definition under field conditions as straw-yellow (Ye. N. Ivanova).

In the fluvioglacial valley of southeast Lithuania and in Belorussia the soils were formed on fine sands, frequently of aeolian origin. In accordance with the systematic list of soils adopted in 1952, the Baltic soil scientists classify the majority of the soils with typical, slightly, and strongly podzolized soils. The soils have a whitish horizon with a thickness of 5-10 cm below the litter layer. Below this, one very often observes the features of an illuvial-humus horizon with a pH of 3-4 (Ye. N. Ivanova called them dwarf or thin podzols).

In the limnoglacial valley of southeast Lithuania and Kaliningrad Oblast' the soils were formed on loess (on parent materials in which silt fractions predominate). The soils were distinguished by high calcareousness (secondary carbonates), but signs of podzolization and water-logging were observed in them. The majority of these soils were heavily cultivated.

In the opinion of Ye.N. Ivanova, the soils in southwest Lithuanian SSR and Kaliningrad Oblast', which developed under the cover of deciduous forests (oak, hornbeam, and others) were similar to the brown earths distinguished in the Polish National Republic.

Young, typical podzolic soils (in Ivanova's opinion, podzolic and sod-podzolic humus illuvial soils) predominate in the massif of aeolian sands of Kurshiy Nering. Quite large areas are covered here with drifting sands which are now being fixed by plantations of mountain pine (Pinus montana).

During discussions of soil profiles, problems of site-quality classes were also touched upon. The scales established by Latvian and Lithuanian soil scientists for site-quality were compared. These scales were established on general principles, however, comparison showed lack of coincidence within the bounds of one site-quality class (10 scale divisions).

On August 27 there was a discussion of the material which had been collected. A decision was adopted to combine further investigations of the soils of the republic with clarification of the following problems:

1) To study the brown earth soils encountered in the extreme western part of the republic, to delineate the area in which they are prevalent and to establish whether they belong in the podzolic or the brown earth soil group;

2) To study the "straw-yellow podzolic" soils of the republic to see if it is possible to separate them into a special bioclimatic subgroup of the podzolic soils of the western maritime regions;

3) To make more precise the position of "dward podzols" of the Lithuanian SSR in the systematic list;

4) To make more precise: a) The separation of the soil profiles formed on two-layer deposits (of the nature of the B horizon in the upper sandy layer) into genetic horizons; and b) the separation of the soil profile developed on thick layers of sand (interpretation of the upper brown horizon where the underlying one is a light color and sandy layer with pseudofibers).

It was decided to issue a communique on the third and fourth problems to the next conference of the All-Union Interdepartmental Commission on the Classification and Nomenclature of Soils.

DIMITRIY PANTELEYMONOVICH GEDEVANISHVILI

Georgian Agricultural Institute and the Department of Soil Science

The Georgian Agricultural Institute, its Soil Science Department, and the entire agronomical community of Georgia have experienced a great loss in the death on December 10, 1958, of Professor Dimitriy Panteleymovich Gedevanishvili, age 74, following a short but grave illness. Professor Gedevenishvili was an agronomist-soil scientist of long standing, an academician of the Academy of Sciences of the Georgian SSR, a deserving scientific worker, and a Doctor of Agricultural Sciences.

D. P. Gedevanishvili led a very fruitful teaching and scientific career for a period of 50 years.

As a student at the Novo-Aleksandriysk Agricultural Institute from 1910-1912, D. P. Gedevanishvili took part in an expedition to study the soils of Asiatic Russia, under the guidance of K. D. Glinka. In 1912-1913 he studied the soils of the Black Sea coast. The results of these studies were partly published in the first volume of the Transactions of the Tbilisi Botanical Garden.

In 1919, D. P. Gedevanishvili was offered the Chair of General Agriculture and Soil Science on the Agronomy Faculty of Tbilisi State University. From 1929 to the end of his days he occupied a similar position without interruption at the Georgian Agricultural Institute.

D. P. Gedevanishvili was one of the founders of higher agricultural education in Georgia, and teacher for a series of generations of agronomists and soil scientists. A number of his students became Doctors and Candidates of Agricultural Sciences, carrying on his ideas. D. P. Gedevanishvili is the co-author of a textbook on soil science, published in the Georgian language.

Parallel to his teaching activity, D. P. Gedevanishvili conducted wide scientific investigations. He studied the soils of Kolkhid plain, the Kobulet bogs, Kakhateria, Pitsundry, etc. These materials served as a basis in the development of a scheme and project for the drainage of Kolkhida.

The soils of almost all irrigated areas of Georgia were studied under the guidance of Dmitriy Panteleymonovich. The results of his work were used in the development of irrigation projects.

D. P. Gedevanishvili's investigations on the distribution and use of agricultural crops are of particular interest. Among these works should be mentioned: "Soils of the subtropical regions of the Georgian SSR and their productivity characteristics" and "Agronomical soil regions of the lower zone of eastern Georgia."

D. P. Gedevanishvili wrote the following general works:

1. "Soil map of the Georgian SSR," published in 1920. This is the first generalized soil map of Georgia; it was exhibited at the Second International Congress of Soil Science. 2. "Agronomic soil map of Georgia for the purpose of allocating agricultural crops"; this was incorporated in the generalized agronomic soil map of the Trans-Caucasus, compiled by three authors: V. P. Smirnov-Loginov, B. Ya. Galstyan, and D. P. Gedevanishvili. 3. "Map of soil-landscape zones of the Georgian SSR." This work reflects the interrelationship between soils, climate, relief, and vegetative cover. More than forty scientific works were written by D. P. Gedevanishvili. He was the first Georgian soil scientist and founder of the Georgian school of soil scientists.

D. P. Gedevanishvili successfully combined scientific and teaching work with social work, and was the chairman of the Georgian Branch of the Society of Soil Scientists. By giving consultations and lectures he gave practical help to the agricultural organizations of the republic.

The bright memory of Dmitriy Panteleymonovich Gedevanishvili, as a learned agronomist-soil scientist, will long live in the hearts of his many friends, comrades, and students.

Georgian Agricultural Institute and
the Department of Soil Science

NINA NIKOLAYEVNA DZENS-LITOVSKAYA 1903-1958

Z. YU. SHOKAL'SKAYA, N. L. BLAGOVIDOV, V. N. SIMAKOV, A. A. KORCHAGIN, and A. F. TSYGANENKO

The noted soil scientist and botanist-geographer, Doctor of Geographical Sciences, Nina Nikolayevna Dzens-Litovskaya died on July 23, 1958, in Vologda Oblast' as a result of an automobile accident. The family of Soviet soil scientists and botanists lost a talented scientist, full of creative force and energy.

N. N. Dzens-Litovskaya was born in Pskov in 1903 into the family of an office worker. In 1930 she graduated from the Geographical Faculty of Leningrad University.

While a student, N. N. Dzens-Litovskaya took part in several expeditions concerned with the study of the mountain forests of Kirgizia. After graduating from the university, she worked from 1930-1934 with soil and geobotanical expeditions in various regions of the USSR (Caucasus, Crimea, Central Asia). In 1935 Nina Nikolayevna became a permanent member of the Geographical-Economic Scientific-Research Institute of Leningrad University and concentrated her studies primarily on the Crimea. The results of her work was her dissertation for a candidate's degree entitled "Soils and vegetation of the Tarkhankutsk Peninsula in Crimea," which she defended in 1940. At the same time, she conducted valuable investigations on the exchange of ash elements in the system soil-vegetation in the Saval'sk forest reserve in Voronezh Oblast'.

During the Great Patriotic War, Nina Nikolayevna participated in geological investigations for defense; after the war she resumed work on her beloved Crimea; and in 1956 defended her doctoral dissertation on the theme "Geographical conditions of soil formation and vegetation in the steppe regions of Crimea." Parallel with her Crimean investigations she participated in expeditions of Leningrad University for the study of soils and vegetation of Leningrad Oblast'.

In 1957 Nina Nikolayevna headed the soils groups of the Vologda Complex Expedition of Leningrad University. She held this position when a tragic accident ended her life, the life of a talented scientist at the height of her creative powers.

The scientific legacy of N. N. Dzens-Lithovskaya is voluminous and varied. She wrote more than 60 and published more than 40 works. The soil scientists and botanists of Leningrad deeply mourn the untimely death of Nina Nikolayevna, who could have yet contributed a great deal more to Soviet science and to the economy of our country.

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